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HEATS OF COMBUSTION OF ORGANIC COMPOUNDS

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ABSTRACT

The literature on the heats of combustion of organic compounds is critically reviewed. A table of "best" values for this constant has been compiled covering all available information on record in the literature.

A method for calculating the heat of combustion from the structural formula of the compound is described, and the values calculated according to this method are tabulated for comparison with the observed values.

The comparison demonstrates that the calculated values are sufficiently accurate for most practical purposes. The difference between calculated and observed values seldom exceeds 1 to 2 per cent except in cases where there is reason to doubt the accuracy of the observed value. In most cases the two values agree within the accuracy of the observed value.

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I. INTRODUCTION

In the present collection of the data on the heats of combustion of organic compounds, an attempt has been made to select the best available value for each compound. The work has been particularly difficult because only a few authors give the necessary information concerning the unit of heat and the thermochemical corrections used, and without this information it is impossible to bring the values to a common basis.

The thermochemical data recorded in the tables have been obtained by the use of the following thermochemical methods: (1) The universal-burner method, (2) the bomb method.

The "universal-burner" method, in the hands of Thomsen, gave results which agreed on the average to not better than 0.5 per cent. Owing to the design of his apparatus, it is applicable only to gases or to substances easily volatile at room temperature, and his values are to be trusted only to the extent to which this condition was realized. This seems to be the consensus of opinion of most workers in thermochemistry. It is, however, necessary to apply two corrections to his values in order to bring them into accord with modern determinations. Both of these corrections are negative. The first one (-0.3 per cent) corrects his thermometer readings to the hydrogen scale, and the second one (-0.1 per cent) corrects for the new determinations of the heat capacity of water. Only the values so corrected are recorded in the tables.

The "bomb-calorimeter" method was first used by Andrews¹ in 1848, the determinations being carried out at a pressure of one atmosphere. In 1883 Berthelot reintroduced the method and improved it considerably. The combustions by this improved method were carried out with oxygen under pressure. The details of the technique have since undergone revolutionary revisions. For particulars the reader is referred to the articles of Richards and his collaborators; Roth and collaborators; Dickinson, Verkade, and collaborators; and Swietoslawski and collaborators.

Of the four different procedures that have been proposed for the measurement of heats of combustion by means of a calorimetric bomb, only two have attained considerable use.² These are known as the "ordinary" or "common" method and the "adiabatic" method. In the "common" method the rise of temperature of the calorimeter is observed while the "jacket" temperature is kept constant. In the "adiabatic" method the temperature of the "jacket" is kept the same as the temperature of the calorimeter and only the initial and final temperatures measured. This latter method may be called the "American adiabatic" method, for it was first proposed by S. W. Holman³ and refined thoroughly by Richards and his collaborators. It has been used extensively only in the United States.

It should be stated at this point that the results of the two methods agree within the limits of experimental error.⁴

¹ Andrews, *Pogg. Ann.*, 75, p. 27; 1848.

² The other two methods are those of Hoeshus and Fery.

³ S. W. Holman, *Proc. Am. Acad.*, 31, p. 252; 1895.

⁴ Dickinson, *Bull. Bureau of Standards*, 11, p. 243; 1915; Schl pfer and Fioroni, *Helv. chim. Acta*, 6, p. 725; 1923.

The method of calibrating the calorimetric system is of the greatest importance.⁵ The methods which have been at times employed by the investigators and pertain to the values recorded are as follows: (1) Calibration by the electrical method; (2) thermal calibration; (3) the additive calibration.

1. The electrical calibration consists in supplying electrically a measured amount of energy to the calorimeter and measuring the temperature rise. The results of such observations give directly the heat capacity of the calorimeter and its contents in joules per degree. The value in calories is then obtained by dividing by the mechanical equivalent of heat. This method forms the basis of the work of Fischer and Wrede; Wrede, Jaeger, and von Steinwehr; Dickinson, Roth, Swartz, Moureu, and André. The work of these investigators is very thorough and of a high order of accuracy.

2. In the thermal method of calibration a standard substance of known heat of combustion is burned in the calorimeter. Where the other calorimetric measurements have been properly carried out this method, using one of the standard substances mentioned below, yields reliable results.

3. In the additive-calibration method the heat capacity of the calorimeter is obtained by adding together the heat capacities of its parts. This method has been used extensively by some French and some Russian investigators. While the work has been carried out with a great deal of zeal, yet essential details of procedure are often entirely lacking and it is thus usually impossible to compare the values with those of other workers. These statements apply to work of Berthelot and his collaborators, Louguinine, Zubov, and a number of other investigators. Recently the values of Zubov's work have been put upon a better basis by Swietoslawski, to whom Zubov turned over most of his experimental material. From the method

⁵ The following are some of the most important references dealing with the calibration of the calorimetric system:

1. Bestimmung des Wasserwertes eines Berthelot'schen Kalorimeter in elektrischen Einheiten, W. Jaeger und H. von Steinwehr, *Verhandl. Deutsch. Phys. Ges.*, **5**, p. 50; 1903; and **5**, p. 353; 1903.
2. Concerning the adiabatic determination of the heat of combustion of organic substances, Richards, Henderson and Frevert, *Proc. Am. Acad.*, **42**, p. 573; 1907.
3. Beitrag zur kalorimetrischen Messung von Verbrennungswärme, W. Jaeger and H. von Steinwehr, *Zs. f. Phys. Chem.*, **53**, p. 153; 1905.
4. Eichung eines Berthelot'schen Verbrennungskalorimeters in elektrischen Einheiten mittels des Platinthermometers, W. Jaeger and H. von Steinwehr, *Ann. d. Phys.* (4), **21**, p. 23; 1906.
5. Ueber die Korrektur für die Wärmestrahlung bei Kalorimetrischen Versuchen, A. Schukarew, *Zs. f. Phys. Chem.*, **56**, p. 453; 1906.
6. An accurate Calorimeter, White, *Phys. Rev.*, **25**, p. 137; 1907.
7. Eichung des Verbrennungskalorimeter und Arbeitsweise, Roth, *Lieb. Ann.*, **373**, p. 249; 1910.
8. Lag effect and other errors of calorimetry, White, *Phys. Rev.*, **31**, p. 562; 1910.
9. A calorimetric arrangement for the new bomb, Phillippe Landrieu, *Bull. Soc. Chim.*, **37**, p. 1340; 1925.

employed by Swietoslawski in correcting Zubov's data, it is evident that Zubov applied most thermometric corrections, except that the heat capacity of his calorimetric system has been erroneously determined. These recalculated values of Zubov are in better agreement with more modern values and are the ones recorded in the tables.

II. STANDARDS FOR COMBUSTION CALORIMETRY

Of the three substances which have been used in the past as standards in combustion calorimetry, only one has been shown by recent researches to meet the requirements of a primary standard. At the third conference of the International Union of Pure and Applied Chemistry held at Lyons,⁶ benzoic acid was adopted as the primary standard. The value chosen for its heat of combustion was the one found by Dickinson,⁷ namely, 6,324 g-cal₁₅ per gram in air or 6,319 g-cal₁₅ per gram in vacuo.⁸ It is more or less tacitly assumed that the above value holds for an isothermal heat of combustion in the neighborhood of 20°.⁹ When converted into absolute joules these values become 26,466 and 26,445, respectively. Dickinson's value was obtained by absolute electrical standardization of his calorimetric system, and the measurements were carried out by the ordinary as well as the adiabatic method.

It is of importance to note here the determinations which have been made of the ratios of the heats of combustion of benzoic acid, naphthalene, and cane sugar. For these determinations Richards and his collaborators employed only the adiabatic method, Verkade and his collaborators the ordinary method, while Swietoslawski and his collaborators and Schläpfer and Fioroni employed both the adiabatic and ordinary methods. These ratios, as summed up by Schläpfer and Fioroni as a result of a very thorough investigation both by the ordinary and the adiabatic methods, are:

$$\frac{\text{Naphthalene}}{\text{Benzoic acid}} = \frac{1.5201}{(\text{air})} \quad \frac{\text{Benzoic acid}}{\text{Sucrose}} = \frac{1.6028}{(\text{air})} \quad \frac{\text{Naphthalene}}{\text{Sucrose}} = \frac{2.4364}{(\text{air})}$$

These ratios are quite similar to those obtained by Dickinson and by Verkade and Coops, jr.¹⁰

SECONDARY STANDARDS.—Recently Verkade and Coops, jr.¹¹ have suggested salicylic acid as a secondary standard. Their suggestion, backed by a large amount of information, certainly merits considera-

⁶ Germany was not represented at that conference.

⁷ Bull. Bur. of Standards, **11**, p. 243; 1915.

⁸ See W. Swietoslawski's defense of this value, J. Chim. Phys., **22**, p. 583; 1925; and P. E. Verkade and J. Coops, Z. Physik. Chem., **118**, p. 123; 1925.

⁹ See Rec. Trav. Chim., **44**, p. 800; 1925, for the temperature coefficient of the heats of combustion of benzoic and salicylic acids.

¹⁰ P. E. Verkade and Coops, jr., Rec. Trav. Chim., **42**, p. 223; 1923.

¹¹ P. E. Verkade and Coops, jr., Rec. Tr. Chim., **43**, p. 561; 1924. Note also the discussion by Swietoslawski upon the establishment of such a secondary standard, Bull. Soc. Chim. (4), **37**, p. 84; 1925.

tion. The value for salicylic acid recommended by these investigators is 5,242 g-cal₁₅ per gram in air and 5,238 g-cal₁₅ per gram in vacuo, that is, $5,242 \times 4.185 = 22,699$ and $5,238 \times 4.185 = 21,921$ absolute joules, respectively.

III. CHOICE OF DATA

Since in the tables below only one value is as a rule given for each compound, it has been necessary to exercise a certain amount of arbitrariness in the choice, but whenever possible the opinions of all workers in thermochemistry, as expressed in their articles, have been taken into account. Naturally, where an author has described carefully his method of procedure, corrections used, etc., or where his method has been sufficiently well established, his values were given preference over those of an author who merely recorded the heats of combustion obtained. The names of all the investigators who have determined the heats of combustion of each compound are, however, recorded. When only one value for a compound is quoted, irrespective of whether or not the value is very reliable, it has been thought desirable to make available even this approximate result. On the whole, for the guidance of the users of the tables, it may be stated that the work of many of the French investigators is not in complete agreement with the best modern determinations. The values are on the whole rather high, but no factor can be employed to correct them, for the variations from author to author are too large. However, the maximum error in most cases is not larger than from 1 to 1.5 per cent.

Preference has been given also to Thomsen's values for gases and for easily volatile compounds over those of Berthelot and his collaborators. The order, however, was reversed for difficultly volatile substances, for Thomsen's values for such compounds are too high.

IV. ABBREVIATIONS, UNITS, AND CONVENTIONS

UNIT EMPLOYED.—The heats of combustion recorded are expressed in absolute kilojoules (at constant pressure) per gram molecular weight of substance in vacuo. Where the investigators indicated the unit of heat employed by them that unit of heat was multiplied by the proper factor to convert the value into absolute kilojoules, otherwise the 18° calorie was assumed to have been used.¹²

VACUUM CORRECTION.—The vacuum correction in very few cases amounts to more than 0.13 to 0.16 per cent. It is quite evident, therefore, that where the accuracy of the method, experimental procedure, and corrections used apparently introduced a much larger error, such a correction is of very little consequence as far as the

¹² The factors used to convert into joules were the ones adopted by the International Critical Tables.

accuracy of the absolute value is concerned. However, it was felt desirable to bring the values to a common basis, and for that reason the values of the investigators have been corrected *ad vacuum* whenever there seemed the slightest justification for it and when the specific gravity of the substances was known. Of the investigators who have done considerable work in thermochemistry and whose results were sufficiently accurate to merit this correction, we might mention Stohmann and collaborators; Zubov,¹³ Roth, Fischer and Wrede; Wrede, Dickinson, Richards and collaborators; Swietoslawski and collaborators; Verkade and collaborators, and a few others. Of course, some of these investigators have themselves applied the correction and record their result upon the basis of weight *in vacuo*.

PHYSICAL STATE.—Unless otherwise specified (by *g*=gas, *v*=vapor, *s*=solid), the values recorded refer to the combustion of the substance in the liquid state, the final products of combustion being gaseous carbon dioxide, liquid water, and nitrogen gas, for C, H, N compounds. In the case of compounds containing other elements consult the discussion under the individual headings.

V. CALCULATION OF HEAT OF COMBUSTION

The calculated values recorded in the tables refer to the heat of combustion of the substance in the liquid state. Whenever, therefore, the heat of combustion of a solid substance is recorded, it is necessary, for the purpose of comparison, to convert that value to the liquid basis. In making that conversion it is necessary, for precision work, to know the molecular heat of fusion referred to 18° C. However, no error of any magnitude is introduced into the calculation of the heat of combustion of a liquid substance by merely subtracting the value of the molecular heat of fusion at the melting point from the heat of combustion in the solid state.

The general basis of calculating heats of combustion is discussed in the paper of Kharasch and Sher.¹⁴ Since the publication of this paper a great deal of experimental work has been carried out by the writer and various collaborators, which enables us to elucidate more fully the general formulas employed. This will be done in papers which will appear elsewhere. To conserve space, factors used will be discussed very briefly, and the user of the table is invited to consult the original papers for the theoretical background and postulates.

It is assumed that, whenever an organic substance is burned in oxygen, the heat generated is due to the interdisplacement of the electrons between the carbon and oxygen atoms. It is assumed, also, that the net amount of these energy interchanges in the form of heat

¹³ The corrected values given by Swietoslawski (*loc. cit.*).

¹⁴ J. Phys. Chem., **29**, pp. 625 to 658; 1925.

is equal to 26.05 kg-cal₁₅ per electron per mole, if the initial and final stages correspond to the arrangement the electron occupies around the carbon nucleus in methane and in carbon dioxide, respectively.

It is easy to perceive, therefore, that since the factor 26.05 corresponds only to certain definite initial and final stages of the electron, whenever a substance is burned which contains some electrons displaced from that position the calculated value should be either smaller or larger than the experimental value, depending upon whether the electrons are nearer or farther from the carbon nucleus than those of our reference position; that is, the arrangement of electrons around the carbon nucleus in methane.

In the case of carbon compounds it is assumed that a sharing of electrons may exist, as represented below. The lines merely indicate the distance which the electrons forming the bond may occupy with respect to the two carbon nuclei A and B.

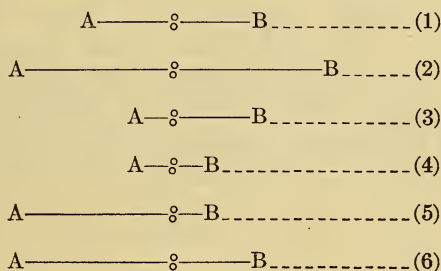


FIG. 1.

Furthermore, if (1) denotes the arrangement of the pair of electrons linking the carbon nuclei in ethane and the expression for the heat of combustion of that compound is $Q = 26.05 \times N$, where N denotes the number of electrons, then it is self-evident that if (2), (3), (4), (5), and (6) differ from ethane only in the arrangement of one pair of electrons, then the expression for the heat of combustion of these compounds should be:

- (1) $Q = 26.05 \times N$
- (2) $Q = 26.05 \times N + a$
- (3) $Q = 26.05 \times N - b$
- (4) $Q = 26.05 \times N - c$, where c is larger than b .
- (5) $Q = 26.05 \times N + d - e$
- (6) $Q = 26.05 \times N + f$

Bonds of the type (5) and (6) need not be considered here, for (6) is merely a special case of (2) and in (5) the two factors ordinarily cancel one another.

The four distinct types of bonds may be illustrated by a consideration of the following molecules:

1. *Bond of type 1.*—Aliphatic hydrocarbons, ethane as a representative compound.

2. *Bond of type 2.*—A carbon-to-carbon linkage in which both groups are weakly electronegative, such as a COOH next to COOH as in oxalic acid or C=O next to COOH as in $\text{CH}_3\text{CO}\cdot\text{COOH}$ or two triphenylmethyl nuclei $(\text{C}_6\text{H}_5)_3\text{C}:\text{C}(\text{C}_6\text{H}_5)_3$.

3. A bond between a carbon of an aliphatic radical or any other C-atom and a carbon atom of a strongly electronegative radical such as phenyl;¹⁵ thus, $\text{C}_6\text{H}_5\cdot\text{CH}_3$.

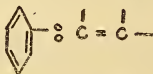
4. A bond between two carbon atoms of two strongly electronegative radicals, such as $\text{C}_6\text{H}_5\cdot\text{C}_6\text{H}_5$, naphthalene, anthracene, etc.

We have thus a general expression for the heat of combustion of organic compounds, $Q = 26.05 \times N$ plus certain correction factors for those electrons that are displaced from the reference position, the sign of the correction factor indicating, except in the case of carbon-oxygen bonds, whether the electrons are displaced *away* from the nucleus of the carbon atoms or *toward* the nucleus.

The correction factors, together with some illustrations, are given below with the proper sign and should always be taken into account whenever calculations are made. In the table only the type formulas will be given. Thus, for example, the heat of combustion of aromatic acids is given by the expression $Q = 26.05 \times N - 3.5$, but in calculating the heat of combustion of a substance such as *o*-toluic acid, we have $Q = 26.05 \times 36 - 3.5 \times 2 = 930.8$, the 3.5 being the correction for the bond as in type 3, and there are two such bonds.

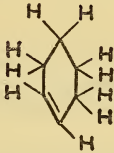
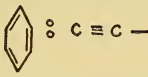
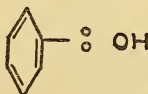
VI. STRUCTURAL CORRECTION FACTORS

Sym- bol	Pair of electrons held between—	For each such grouping add or subtract as indicated
a	Aromatic radical \circ Aliphatic radical Examples: 1. Mesitylene $Q = 26.05 \times 48 - 3 \times 3.5 = 1239.9$. 2. Tertiary butylbenzene $Q = 26.05 \times 54 - 3.5 = 1403.2$.	-3.5
b	Aromatic radical \circ Aromatic radical Examples: 1. Naphthalene $Q = 26.05 \times 48 - 6.5 \times 2 = 1233.4$. 2. Diphenyl $Q = 26.05 \times 58 - 6.5 = 1497.9$.	-6.5
c	Ethylene bond $-\overset{ }{\underset{ }{\text{C}}}=\overset{ }{\underset{ }{\text{C}}}-$ Examples: 1. Trimethylethylene $Q = 26.05 \times 30 + 13 = 794.5$. 2. Diamylene $Q = 26.05 \times 60 + 13 = 1576.0$.	+13.0

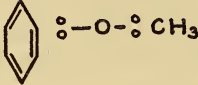
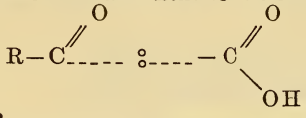
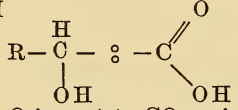
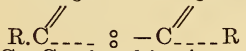
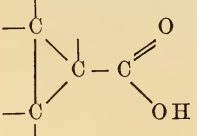


¹⁵ Consult paper of Kharasch and Marker, J. A. C. S., 48, p. 3130; 1926, for a table of relative electronegativity of organic radicals, and also Kharasch and Flenner (to be published).

VI. STRUCTURAL CORRECTION FACTORS—Continued

Sym- bol	Pair of electrons held between—	For each such grouping add or subtract as indicated
d	Aromatic radical carbon \circ Vinyl radical ----- Example: Styrene $Q = 26.05 \times 40 + 13 - 6.5 = 1048.5$.	-6.5
e	Ethylene bond in ring system, as in cyclohexene ----- <div style="text-align: center;">  </div> <p>Examples: 1. Tetrahydrobenzene $Q = 26.05 \times 34 + 6.5 = 892.2$. 2. Methyl-1-cyclohexene-1 $Q = 26.05 \times 40 + 6.5 = 1048.5$.</p> <p style="text-align: center;"><i>Acetylene bond</i></p>	+6.5
g	One or more replaceable hydrogens $-C \equiv C-$ ----- Example: Heptine-1 $Q = 26.05 \times 40 + 46.1 = 1088.1$.	+46.1
h	No replaceable hydrogens $R-C \equiv C-R$ ----- Example: Dimethyl diacetylene $Q = 26.05 \times 30 + 33.1 \times 2 = 847.7$.	+33.1
i	Aromatic radical carbon \circ Acetylene radical ----- <div style="text-align: center;">  </div> <p>Example: Phenyl ethine $Q = 26.05 \times 38 + 46.1 - 6.5 = 1029.5$.</p> <p style="text-align: center;"><i>Alcohols</i></p>	-6.5
j	Aliphatic radical \circ Hydroxyl group (Primary alcohol) ----- Example: Methyl alcohol $Q = 26.05 \times 6 + 13 = 169.3$.	+13.0
k	Secondary radical \circ Hydroxyl group (Secondary alcohol) ----- Examples: 1. Cyclohexanol $Q = 26.05 \times 34 + 6.5 = 892.7$. 2. Amyl phenyl propargyl alcohol $Q = 26.05 \times 72 + 33.1 + 6.5 - 3.5 = 1911.7$.	+6.5
l	Tertiary radical \circ Hydroxyl group (Tertiary alcohol) ----- Examples: 1. Methyl diethyl carbinol $Q = 26.05 \times 36 + 3.5 = 941.3$. 2. Diphenyl phenyl ethinyl carbinol. $Q = 26.05 \times 98 + 33.1 + 3.5 - 6.5 - 3.5 \times 2 = 2576.0$.	+3.5
m	Aromatic radical \circ Hydroxyl group ----- <div style="text-align: center;">  </div> <p>Examples: 1. <i>m</i>-Cresol $Q = 26.05 \times 34 + 3.5 - 3.5 = 885.7$. 2. Thymohydroquinol $Q = 26.05 \times 50 + 3.5 \times 2 - 3.5 \times 2 = 1302.5$.</p>	+3.5
o	Acetal linkage $R.C \circ -(O-R_1)_2$ ----- where R and R_1 are aliphatic radicals. Examples: 1. Glycol acetal $Q = 26.05 \times 20 + 19.5 \times 2 = 560.1$. 2. Dipropyl methylal $Q = 26.05 \times 40 + 19.5 \times 2 = 1081.1$.	+19.5

VI. STRUCTURAL CORRECTION FACTORS—Continued

Symbol	Pair of electrons held between—	For each such grouping add or subtract as indicated
p	Aromatic ethers.....  Examples: 1. <i>m</i> -Cresol methyl ether. $Q = 26.05 \times 40 + 19.5 - 3.5 = 1058.5$. 2. Resorcinol dimethyl ether. $Q = 26.05 \times 38 + 19.5 \times 2 = 1028.9$.	+19.5
q	Aliphatic aldehydes $R-\overset{\text{H}}{\underset{\text{O}}{\text{C}}}=\text{O}$ Example: Acetaldehyde $Q = 26.05 \times 10 + 13.0 = 273.5$.	+13.0
r	Aromatic aldehydes $R-\overset{\text{H}}{\underset{\text{O}}{\text{C}}}=\text{O}$ Example: <i>p</i> -Hydroxybenzaldehyde. $Q = 26.05 \times 30 + 13.0 - 3.5 + 3.5 = 794.5$.	+13.0
s	Aliphatic ketones $R-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}=\text{R}$ Examples: 1. Methyl propyl ketone. $Q = 26.05 \times 28 + 6.5 = 735.6$. 2. Allylacetone $Q = 26.05 \times 32 + 6.5 + 13.0 = 866.1$.	+6.5
t	Aromatic ketones..... $R-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}=\text{C}_6\text{H}_5$. Example: Benzophenone $Q = 26.05 \times 60 + 6.5 - 3.5 \times 2 = 1562.5$.	+6.5
u	If $R-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}=\text{O}$ radical is next to COOH radical, as in..... 	+13
v	If $R-\overset{\text{R}}{\underset{\text{OH}}{\text{C}}}$ radical is next to COOH, as in..... 	+6.5
w	If $R-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}=\text{O}$ is next to CO, as in..... 	+6.5
x	For $-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}=\text{C}=\text{C}-$ bond in <i>cis</i> compounds.....	+16.5
y	For $-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}=\text{C}=\text{C}-$ bond in <i>trans</i> compounds.....	+13.0
z	For trimethylene ring in carboxylic acids, as in.....  Example: Trimethylenecarboxylic acid. $Q = 26.05 \times 18 + 13 = 481.9$.	+13.0

VI. STRUCTURAL CORRECTION FACTORS—Continued

Sym- bol	Pair of electrons held between—	For each such grouping add or subtract as indicated
aa	For cyclobutane ring in carboxylic acids----- <div style="text-align: center;"> </div> <p>Example: Tetramethylenedicarboxylic acid. $Q = 26.05 \times 24 + 13 = 638.2$.</p>	+13.0
bb	Acid anhydride $R-C(=O)-O-C(=O)-R$ ----- <p>Example: Succinic anhydride $Q = 26.05 \times 14 + 10 = 374.3$.</p>	+10.0
cc	Lactone $H-\overset{\overset{H}{ }}{\underset{\underset{H}{ }}{\overset{\overset{H}{ }}{C}}}-\overset{\overset{H}{ }}{\underset{\underset{H}{ }}{\overset{\overset{H}{ }}{C}}}-C(=O)-O$ ----- <p>Example: Saccharic acid lactone. $Q = 26.05 \times 24 + 13 + 3.5 + 6.5 + 13.0 = 662.2$.</p>	+13.0
dd	Esters (Aliphatic)----- <div style="text-align: center;"> </div> <p>Example: Methyl acetate $Q = 26.05 \times 14 + 13 = 381.2$.</p>	+16.5
ee	Aliphatic radical :NH_2 ----- <p>(Primary aliphatic amine)</p> <p>Example: Propyl amine $Q = 26.05 \times 21 + 13 = 560.1$.</p>	+13.0
ff	Aliphatic radical $\text{:N}(\text{H})_2$ - Aliphatic radical----- <p>(Secondary aliphatic amine)</p> <p>Example: Benzylethylamine $Q = 26.05 \times 49 + 19.5 - 3.4 = 1292.5$.</p>	+19.5
gg	Aliphatic radical $\text{:N}(\text{H})_3$ (Aliphatic radical) ₂ ----- <p>(Tertiary aliphatic amines)</p>	+26.0
hh	Aromatic radical carbon :N (Ammonia type of nitrogen)-----	-3.5
jj	Aromatic radical $\text{:N}(\text{H})_2$ ----- <p>(Primary aromatic amine)</p> <p>Example: <i>p</i>-Toluidine $Q = 26.05 \times 37 + 6.5 - 3.5 - 3.5 = 963.3$.</p>	+6.5
kk	Aromatic radical $\text{:N}(\text{H})_2$ - aromatic radical----- <p>(Secondary aromatic amine)</p> <p>Example: Diphenylamine $Q = 26.05 \times 59 + 13.0 - 3.5 \times 2 = 1542.9$.</p>	+13.0
ll	Aromatic radical $\text{:N}(\text{H})_3$ (Aromatic radical) ₂ ----- <p>Example: Triphenylamine $Q = 26.05 \times 87 + 19.5 - 3.5 \times 3 = 2275.3$.</p>	+19.5
mm	For substituted amides, as in $O=C(\text{R})-N(\text{H})-CH_3$ -----	+6.5

VI. STRUCTURAL CORRECTION FACTORS—Continued

Sym- bol	Pair of electrons held between—	For each such grouping add or subtract as indicated
nn	For Nitrile radical aliphatic or aromatic, $RC\equiv N$ ----- Example: Propionitrile $Q=26.05 \times 17 + 16.5 = 459.3$.	+16.5
pp	Aromatic radical carbon $\% C\equiv N$ ----- Example: Benzonitrile $Q=26.05 \times 33 + 16.5 - 6.5 = 869.6$.	-6.5
qq	For Carbylamine radical, aliphatic----- $R-N=C$ Example: Propyl carbylamine $Q=26.05 \times 23 + 33.1 = 632.2$.	+33.1
rr	Aliphatic radical $\% N \begin{smallmatrix} \diagup O \\ \diagdown O \end{smallmatrix}$ ----- Example: Nitromethane $Q=26.05 \times 6 + 13 = 169.3$.	+13.0
ss	Aromatic radical $\% N \begin{smallmatrix} \diagup O \\ \diagdown O \end{smallmatrix}$ ----- Examples: 1. Dinitrobenzene $Q=26.05 \times 26 + 13 \times 2 = 703.3$. 2. Nitrotoluene $Q=26.05 \times 34 + 13 - 3.5 = 895.2$.	+13

No equations are given for the fluorine, chlorine, and sulphur compounds. However, an examination of the data reveals that the general form of the equation $Q = 26.05 \times N + a$ holds fairly well, and it is only necessary to evaluate "a" to obtain the equations for these substances. In the case of sulphur compounds it is also necessary to use a factor different from 26.05 for the sulphur atoms which are burned to SO_2 or SO_3 .

VII. INDEX OF COMPOUNDS, BY CLASSES

The compounds recorded in the tables are classified in accordance with the distinct types of organic molecules which they represent. The calculation of the heats of combustion is thus facilitated.¹⁶

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¹⁶ A substance such as cinnamic acid would in this classification come under the heading of unsaturated aliphatic acid. Other similar substances were classified in the same manner.

2. CHO COMPOUNDS

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VIII. TABLES OF DATA

1. CH COMPOUNDS

1. SATURATED HYDROCARBONS (ALIPHATIC)

$$Q = 26.05 \times N$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
CH ₄	Methane (g).....	16	8	¹ 210.8	881.6	208.4	223; cf. 136, 37, 2, 65.
C ₂ H ₆	Ethane (g).....	30	14	² 368.4	1,540.7	364.7	223; cf. 136.
C ₃ H ₈	Propane (g).....	44	20	³ 526.3	2,201.0	521.0	223; cf. 136.
C ₄ H ₁₀	Isobutane (g) (trimethyl-methane).....	58	26	⁴ 683.4	2,858.0	677.3	223.
C ₅ H ₁₂	n-Pentane (g).....	72.10	32	838.3	3,511.6	833.6	170.
C ₅ H ₁₂	n-Pentane.....	72.10	32	833.4	3,491.1	833.6	170.
C ₅ H ₁₂	Isopentane (g).....	72.10	32	843.5	3,533.4	833.6	170.
C ₅ H ₁₂	Isopentane ⁵	72.10	32	838.3	3,511.6	833.6	170.
C ₅ H ₁₂	Tetramethylmethane (g).....	72.10	32	⁶ 842.6	3,523.8	833.6	223.
C ₆ H ₁₄	n-Hexane.....	86.11	38	{ 991.4 989.8	{ 4,149.0 4,139.3	989.9	{ 185. 215.
C ₆ H ₁₄	Diisopropyl (v).....	86.11	38	{ 993.9 1,137.3	{ 4,156.5 4,756.2	989.9	{ 223. 114.
C ₇ H ₁₆	n-Heptane.....	100.13	44	{ 1,149.9 1,147.9	{ 4,812.3 4,804.0	1,146.2	246.
C ₇ H ₁₆	2-Methylhexane.....	100.13	44	1,148.9	4,808.1	1,146.2	246.
C ₇ H ₁₆	3-Methylhexane.....	100.13	44	1,148.9	4,808.1	1,146.2	246.
C ₇ H ₁₆	2,2-Dimethylpentane.....	100.13	44	1,148.9	4,808.1	1,146.2	246.
C ₇ H ₁₆	2,3-Dimethylpentane.....	100.13	44	1,148.9	4,808.1	1,146.2	246.
C ₇ H ₁₆	3,3-Dimethylpentane.....	100.13	44	1,147.9	4,804.0	1,146.2	246.
C ₇ H ₁₆	2,4-Dimethylpentane.....	100.13	44	1,148.9	4,808.1	1,146.2	246.
C ₇ H ₁₆	3-Ethylpentane.....	100.13	44	1,149.9	4,812.3	1,146.2	246.
C ₇ H ₁₆	2,2,3-Trimethylbutane.....	100.13	44	1,147.9	4,804.0	1,146.2	246.
C ₈ H ₁₈	n-Octane.....	114.14	50	{ 1,302.7 1,304.7 1,305.2	{ 5,447.9 5,458.9 5,467.5	1,302.5	{ 215. 154. 163.
C ₈ H ₁₈	2,5-Dimethylhexane.....	114.14	50	1,303.3	5,463.0	1,302.5	154.
C ₈ H ₁₈	2-Methylheptane.....	114.14	50	1,306.1	5,464.7	1,302.5	154.
C ₈ H ₁₈	3,4-Dimethylhexane.....	114.14	50	1,303.7	5,454.7	1,302.5	154.
C ₈ H ₁₈	3-Ethylhexane.....	114.14	50	1,302.3	5,448.8	1,302.5	154.
C ₈ H ₁₈	2,2,4-Trimethylpentane.....	114.14	50	1,303.9	5,457.0	1,302.5	246.
C ₈ H ₁₈	Hexamethylethane (s).....	114.14	50	1,301.8	5,448.3	1,302.5	246.
C ₁₀ H ₂₂	Decane.....	142.18	62	1,610.2	6,733.9	1,615.1	215.
C ₁₀ H ₂₂	Diisooamyl.....	142.18	62	1,615.8	6,757.3	1,615.1	153; cf. 244.
C ₁₆ H ₃₄	Hexadecane (s).....	226.27	98	2,559.1	10,709.8	2,552.9	192.
C ₂₆ H ₅₄	Elcosane (s).....	282.34	122	3,183.1	13,321.3	3,178.1	192.

¹ The above value is the average of 9 determinations which show a maximum variation of 1.1 per cent.

² The variation between the highest and lowest result equals 1.1 per cent.

³ The variation between the highest and lowest result equals 0.9 per cent.

⁴ The variation between the highest and lowest result equals 0.4 per cent.

⁵ Note the large difference obtained by (170) for the two isomeric pentanes. This difference is rather unusual, particularly in view of the fact that the 9 isomeric heptanes recorded in this report show almost identical heats of combustion. The heptanes used for this purpose at the Bureau of Standards were of a very high degree of purity. In view of that fact, no great reliance should be attached to the value for isopentane until it is substantiated by other determinations.

⁶ Value uncertain, since tetramethylmethane mixed with butylene was burned. The variation between the highest and lowest result equals 0.2 per cent.

VIII. TABLES OF DATA—Continued

1. CH COMPOUNDS—Continued

[2. POLYMETHYLENES

$$Q=26.05 \times N^7$$

Formula	Name	Molecular weight	Number of electrons (<i>N</i>)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₃ H ₆ -----	Trimethylene (g)-----	42	18	496.8	2,077.6	-----	223; cf. 37.
C ₅ H ₁₀ -----	Methyleyclobutane-----	70.08	30	784.2	3,279.5	781.5	215.
C ₅ H ₁₀ -----	Cyclopentane-----	70.08	30	783.6	3,277.0	781.5	215.
C ₆ H ₁₂ -----	Methyleyclopentane-----	84.10	36	937.9	3,922.3	937.8	215.
C ₆ H ₁₂ -----	Cyclohexane-----	84.10	36	{ 936.3 937.2 940.6 912.5	{ 3,915.6 3,925.9 3,933.6 3,818.8	{ 937.8 ----- ----- -----	{ 215. 165. 152. 91.
C ₆ H ₁₀ -----	Bicyclohexane (0,1,3)-----	82.08	34	912.5	3,818.8	-----	91.
C ₇ H ₁₄ -----	1,3-Dimethyleyclopentane-----	98.11	42	1,090.7	4,561.3	1,094.1	215.
C ₇ H ₁₄ -----	Methyleyclohexane-----	98.11	42	1,091.8	4,565.9	1,094.1	215; cf. 114.
C ₇ H ₁₄ -----	Cycloheptane-----	98.11	42	1,087.3	4,547.1	1,094.1	114.
C ₇ H ₁₂ -----	Bicycloheptane-----	96.10	-----	1,030.3	4,308.7	-----	163.
C ₈ H ₁₆ -----	1,2,4-Trimethyleyclopentane-----	112.13	48	1,245.4	5,208.3	1,250.4	215.
C ₈ H ₁₆ -----	1,1-Dimethyleyclohexane-----	112.13	48	1,242.5	5,196.1	1,250.4	215.
C ₈ H ₁₆ -----	1,3-Dimethyleyclohexane-----	112.13	48	⁸ 1,238.0	5,177.3	1,250.4	215.
C ₈ H ₁₆ -----	1,4-Dimethyleyclohexane-----	112.13	48	⁸ 1,228.8	5,138.8	1,250.4	215.
C ₈ H ₁₆ -----	Methyleycloheptane-----	112.13	48	1,244.5	5,204.5	1,250.4	215.
C ₉ H ₁₈ -----	Methyl-1- <i>n</i> -propyleyclopentane-----	126.14	54	1,401.4	5,860.7	1,406.7	215.
C ₉ H ₁₈ -----	1,2,3-Trimethyleyclohexane-----	126.14	54	1,396.0	5,837.7	1,406.7	215.
C ₉ H ₁₈ -----	1,3,3-Trimethyleyclohexane-----	126.14	54	⁸ 1,394.7	5,832.6	1,406.7	215.
C ₉ H ₁₈ -----	1,3,4-Trimethylhexahydrobenzene-----	126.14	54	⁹ 1,383.0	5,788.7	1,406.7	144.
C ₉ H ₁₈ -----	Ethyleycloheptane-----	126.14	54	1,406.8	5,883.2	1,406.7	215.
C ₁₀ H ₁₈ -----	Fenchane-----	138.14	58	1,502.8	6,284.7	1,510.9	215.
C ₁₀ H ₁₈ -----	Thujane-----	138.14	58	1,506.4	6,310.3	-----	175.
C ₁₀ H ₁₈ -----	Decahydronaphthalene (<i>cis</i>).-----	138.14	58	1,502.5	6,288.0	1,510.9	169; cf. 173, 82.
C ₁₀ H ₁₈ -----	Decahydronaphthalene (<i>trans</i>).-----	138.14	58	{ 1,499.5 1,497.4	{ 6,275.4 6,266.6	{ 1,510.9 -----	{ 105. 173; cf. 82.
C ₁₀ H ₂₀ -----	Methyl-1- <i>n</i> -propyl-3-cyclohexane-----	140.16	58	1,502.9	6,285.1	1,510.9	215.
C ₁₀ H ₂₀ -----	<i>p</i> -Menthane ¹⁰ (1-Isopropyl-4-methyleyclohexane).-----	140.16	60	1,514.6	6,334.1	1,563.0	215.
C ₁₄ H ₂₆ -----	3,3-Dimethyldicyclohexyl (<i>m</i> -Hexahydroditolyl).-----	194.21	82	2,105.9	8,806.9	2,136.1	215.

Except for trimethylene and its derivatives and bicyclo compounds containing trimethylene rings.

Swietoslawski (J. Am. Ch. Soc., 42, p. 1315), 1920, believes that the heats of combustion of these compounds are in error and recommends that they be redetermined.

⁹ This value is probably in error. The work of this investigator does not agree well with the values of modern workers.

¹⁰ The author (215) calls the compound "Caromenthane." The heat of combustion of this compound would certainly bear reinvestigation.

VIII. TABLES OF DATA—Continued

1. CH COMPOUNDS—Continued

3. AROMATIC HYDROCARBONS

$$Q = 26.05 \times N - 3.5a - 6.5b$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₆ H ₆ -----	Benzene (v)-----	78.05	30	787.2	3,294.4	-----	200.
C ₆ H ₆ -----	Benzene-----	78.05	30	{ 783.4 782.3	{ 3,277.7 3,277.1	781.5	153.
C ₇ H ₈ -----	Toluene-----	92.06	36	{ 937.0 934.2	{ 3,920.4 3,913.4	934.3	165; cf. 154. 152. 165; cf. 203, 153.
C ₈ H ₁₀ -----	<i>o</i> -Xylene-----	106.08	42	{ 1,094.2 1,091.7	{ 4,578.1 4,567.7	1,087.1	154. 152.
C ₈ H ₁₀ -----	<i>m</i> -Xylene-----	106.08	42	{ 1,091.7 1,088.4	{ 4,567.7 4,559.3	1,087.1	152. 165; cf. 154, 203.
C ₈ H ₁₀ -----	<i>p</i> -Xylene-----	106.08	42	1,089.1	4,556.8	1,087.1	154; cf. 152.
C ₈ H ₁₀ -----	Ethylbenzene-----	106.08	42	1,091.2	4,565.6	1,087.1	152; cf. 138. 4. ¹¹
C ₉ H ₁₂ -----	Mesitylene-----	120.10	48	1,243.6	5,203.2	1,239.9	152; cf. 203.
C ₉ H ₁₂ -----	<i>n</i> -Propylbenzene-----	120.10	48	1,246.4	5,214.9	1,246.9	152; cf. 73.
C ₉ H ₁₂ -----	Isopropylbenzene-----	120.10	48	1,247.3	5,218.7	1,246.9	152; cf. 73.
C ₉ H ₁₂ -----	Pseudocumene (1,2,4-Tri- methylbenzene)-----	120.10	48	1,241.7	5,195.3	1,239.9	152.
C ₁₀ H ₁₄ -----	<i>tert</i> -Butylbenzene-----	134.11	54	1,400.4	5,859.3	1,403.2	152; cf. 153.
C ₁₀ H ₁₄ -----	1,2,4,5-Tetramethylbenzene (s) (Durene)-----	134.11	54	1,393.6	5,832.2	1,392.7	188.
C ₁₀ H ₁₄ -----	<i>iso</i> -Propyltoluene (1,4) (Cy- mene)-----	134.11	54	{ 1,412.3 1,402.8	{ 5,910.5 5,866.5	1,399.7	182. 203.
C ₁₀ H ₁₄ -----	<i>n</i> -Propyltoluene (1,3)-----	134.11	54	¹² 1,405.4	5,878.8	1,399.7	73.
C ₁₀ H ₁₄ -----	Isopropyltoluene (1,3)-----	134.11	54	¹² 1,409.5	5,895.9	1,399.7	73.
C ₁₁ H ₁₆ -----	Pentamethylbenzene (s)-----	148.13	60	1,554.0	6,503.5	1,545.5	188.
C ₁₂ H ₁₈ -----	Hexamethylbenzene (s)-----	162.14	66	1,711.9	7,164.3	1,700.3	188.
C ₁₃ H ₁₂ -----	Diphenylmethane (s)-----	168.10	64	1,655.0	6,926.2	1,660.2	182; cf. 179.
C ₁₄ H ₁₄ -----	Dibenzyl (s)-----	182.11	70	1,810.6	7,577.4	1,816.5	182.
C ₁₅ H ₁₅ -----	Triphenylmethyl (s) ¹³ -----	243.12	91	¹⁴ 2,378.5	9,946.9	2,373.5	179.
C ₁₉ H ₁₆ -----	Triphenylmethane (s)-----	244.13	92	{ 2,379.3 2,388.7	{ 9,957.4 9,996.9	2,386.1	182. 179.
C ₂₅ H ₂₀ -----	Tetraphenylmethane (s)-----	320.16	120	3,102.4	12,974.2	3,112.0	179.

¹¹ The authors (4) report the heats of combustion of two samples of ethylbenzene prepared by the Fittig and Clemensen methods, respectively. The calorimetric determinations were carried out by Langbein and agree within 0.1 per cent with the value recorded by (152). Of interest is the fact that, while the two samples have almost identical heats of combustion within 0.2 per cent, the sample obtained by the Clemensen method has the higher density and index of refraction.

¹² The values of this investigator are about 0.4 per cent too high as compared with those of Richards and Barry (16).

¹³ The author (179) gives, also, the heat of combustion of triphenylmethyl peroxide and the heat of combustion of the addition product of hexaphenylethane and ethyl acetate.

¹⁴ This molecule contains one displaced electron; hence the formula for it becomes $26.05 \times N + 13 = 2,373.5$.

4. AROMATIC HYDROCARBONS

(Two or more aromatic nuclei linked together)

$$Q = 26.05 \times N - 3.5a - 6.5b$$

C ₁₀ H ₈ -----	Naphthalene (s)-----	128.06	48	{ 1,232.5 1,231.8 1,229.9	{ 5,158.0 5,150.2 5,147.1	1,233.4	80. 52. 221; cf. 188, 241, 232, 63.
C ₁₂ H ₁₀ -----	Diphenyl (s)-----	154.08	58	1,493.6	6,250.7	1,497.9	188; cf. 47. ¹⁵
C ₁₂ H ₁₀ -----	Acenaphthene (s), (<i>peri</i> - ethylenenaphthylene)-----	154.08	58	1,491.3	6,241.1	1,491.0	182.

¹⁵ These authors give the heats of combustion of a freshly prepared sample of diphenyl and one 20 years old, the difference being 11.2 kg-cal₁₅ per mole. The authors accept the higher value of 1,510.1 kg-cal₁₅ for the fresh sample as the correct value and believe that the new sample is of a higher degree of purity than the old sample.

VIII. TABLES OF DATA—Continued

1. CH COMPOUNDS—Continued

4. AROMATIC HYDROCARBONS—Continued

(Two or more aromatic nuclei linked together)

$$Q = 26.05 \times N - 3.5a - 6.5b$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₁₃ H ₁₀ -----	Fluorene (s)-----	166.08	62	1,584.9	6,628.1	1,595.1	163.
C ₁₄ H ₁₀ -----	Anthracene (s)-----	178.08	66	1,693.4	7,086.9	1,705.3	188.
C ₁₄ H ₁₀ -----	Phenanthrene (s)-----	178.08	66	1,700.4	7,116.2	-----	240.
C ₁₅ H ₁₂ -----	Chrysene (s)-----	228.10	84	1,691.6	7,079.3	-----	217.
C ₁₅ H ₁₂ -----	Retene (s) (Methylisopropylphenanthrene).	234.14	90	1,692.5	7,083.1	1,693.3	188.
C ₂₄ H ₁₈ -----	1,3,5-Triphenylbenzene (s)---	306.14	114	2,139.1	8,952.1	2,159.2	182.
C ₂₆ H ₂₀ -----	Dianthracene (s)-----	356.16	-----	2,306.8	9,653.9	2,311.5	182.
				2,936.7	12,290.1	2,940.2	182.
				3,382.9	14,147.3	-----	240.

5. UNSATURATED COMPOUNDS

(Aliphatic-ethylene)

$$Q = 26.05 \times N + 13$$

C ₂ H ₄ -----	Ethylene (g)-----	28	12	345.4	1,444.5	325.6	136.
C ₃ H ₆ -----	Propylene (g)-----	42	18	16 331.6	1,387.8	-----	223.
C ₄ H ₆ -----	Isobutylene (g)-----	56	24	490.2	2,051.5	481.9	223; cf. 37.
C ₅ H ₁₀ -----	Amylene-----	70	30	647.2	2,708.5	638.2	223.
C ₅ H ₁₀ -----	Trimethylethylene (v)-----	70	30	803.4	3,362.2	794.5	65; cf. 98.
C ₅ H ₁₀ -----	Trimethylethylene liquid-----	70.08	-----	803.6	3,363.1	794.5	223.
C ₆ H ₁₂ -----	Hexylene-----	84.10	36	796.0	3,328.9	-----	215.
C ₆ H ₁₂ -----	Diallyl (v)-----	82	34	952.6	3,983.8	950.8	215.
C ₆ H ₁₂ -----	Diisobutylene ¹⁷ -----	112.13	48	928.1	3,884.1	911.7	223.
C ₁₀ H ₂₀ -----	Diamylene-----	140.16	60	903.4	3,778.0	-----	38.
C ₁₀ H ₂₄ -----	Triisobutylene ¹⁸ -----	168.19	72	1,252.4	5,237.5	1,263.4	128.
				1,582.2	6,616.8	1,576.0	65.
				1,853.3	7,771.4	1,888.6	128.

¹⁶ Thomsen's value is probably more reliable than the higher value of Mixer.¹⁷ (CH₃)₂CH.CH:CH.CH.(CH₃)₂.¹⁸ (CH₃)₂CH.C[CH₂.CH.(CH₃)₂]:CH.CH (CH₃)₂.

6. UNSATURATED HYDROCARBONS

(Aromatic)

$$Q = 26.05 \times N + 13 - 6.5d$$

C ₈ H ₈ -----	Styrene (Phenylethylene)---	104.06	40	1,045.4	4,375.0	1,048.5	182.
				1,047.1	4,386.3	-----	7; cf. 138,
C ₉ H ₁₀ -----	α-Methylstyrene-----	118.08	46	1,202.9	5,038.9	1,204.8	104. ^{10,20}
C ₉ H ₁₀ -----	β-Methylstyrene (p-Tolyl-ethylene).	118.08	46	1,202.4	5,036.9	1,204.8	7; cf. 104.
C ₁₀ H ₁₂ -----	α,β-Dimethylstyrene (s)-----	132.10	52	1,357.2	5,685.3	1,361.1	163; cf. 7,
C ₁₀ H ₁₂ -----	β-Ethylstyrene-----	132.10	52	1,346.1	5,638.8	1,361.1	104.
							6; cf. 7.

¹⁹ The author (104) gives values for styrene and substitution products of that compound which are about 1.4 per cent higher than the values given by (7). As the details of the former (8) work are entirely lacking, and since, in general, the work of (7) is most painstaking, we may safely assume that the values of (104) are in error, and that his results are at least 0.8 per cent too high. No greater accuracy than 0.3 to 0.5 per cent can even then be attached to his values.

²⁰ Recently Swietoslowski and Popov (J. chim. phys., 22, p. 397; 1925) have attempted to correct Lemoult's values by introducing a correction of -0.5 per cent. While it is possible that the result of this investigator contains a systematic error, yet we do not believe that this correction brings all of Lemoult's values into agreement with those of later investigators, which indicates other sources of error. In the tables the corrected values are recorded.

VIII. TABLES OF DATA—Continued

1. CH COMPOUNDS—Continued

6. UNSATURATED HYDROCARBONS—Continued

(Aromatic)

$$Q = 26.05 \times N + 13 - 6.5d$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₁₀ H ₁₂ -----	Phenyl-1-butene-2-----	132.10	52	1,361.2	5,702.1	1,364.1	7.
C ₁₀ H ₁₂ -----	Phenyl-1-butene-3-----	132.10	52	1,356.9	5,675.9	1,364.1	138.
C ₁₁ H ₁₄ -----	Phenyl-1-pentene-2-----	146.11	58	1,510.0	6,325.4	1,517.4	6.
C ₁₂ H ₁₆ -----	β , β -Diethylstyrene-----	160.13	64	1,664.9	6,974.3	1,673.7	6; cf. 7.
C ₁₄ H ₁₂ -----	Stilbene (s) (symm. Diphenylethylene).-----	180.10	68	1,765.0	7,381.2	1,771.4	183; cf. 163, 144, 9.
C ₁₄ H ₁₂ -----	Isostilbene-----	180.10	68	1,770.9	7,405.9	1,771.4	9.
C ₁₅ H ₁₄ -----	α , β -Methylphenylstyrene (s).-----	194.11	74	¹¹ 1,937.9	8,106.2	1,927.7	104.
C ₁₆ H ₁₄ -----	Diphenylbutadiene (s) (labile).-----	206.11	78	2,056.9	8,608.1	2,044.9	172.
C ₁₆ H ₁₄ -----	Diphenylbutadiene (s) (cis-cis).-----	206.11	78	2,035.1	8,516.9	2,044.9	172.
C ₁₆ H ₁₄ -----	Diphenylbutadiene (s) (trans-trans).-----	206.11	78	2,030.3	8,496.8	2,031.9	172. ²²
C ₁₈ H ₁₆ -----	Diphenylhexatriene (s) ²³ -----	232.13	88	2,287.7	9,574.0	2,318.4	172.
C ₁₈ H ₁₈ -----	1, 6-Diphenylhexadiene-1, 5 (s).-----	234.14	90	2,342.2	9,811.5	2,355.5	163.
C ₁₈ H ₁₈ -----	Dibenzylbutadiene (s)-----	234.14	90	2,341.0	9,797.1	2,357.5	172.
C ₁₈ H ₂₀ -----	Diphenyl-1, 4-ethyl-1-butene-3.-----	²⁴ 236.15	92	2,372.6	9,939.3	2,399.6	7.
C ₂₀ H ₁₆ -----	Diphenylstyrene (s)-----	256.13	96	²⁵ 2,508.6	10,493.5	2,494.3	164.

²¹ This value is about 0.6 per cent too high. A better value would be 1,929.2 See footnotes 19 and 20^a p. 376.

²² For *trans* isomers the correction is 6.5 for the double bond. Consult p. 363.

²³ The purity of this product is rather questionable.

²⁴ C₆H₅.CH (CH₂.CH₃).CH₂.CH=CH.C₆H₅.

²⁵ The values of this investigator for this series are uniformly too high by 0.5 per cent. A better value would be 2,496.1 kg-cal₁₅.

7. HYDROAROMATIC HYDROCARBONS ²⁶

(Unsaturated)

$$Q = 26.05 \times N + 6.5e$$

C ₆ H ₈ -----	Dihydrobenzene-----	80.06	32	{ 833.2 847.8 898.0	{ 3,484.4 3,548.0 3,755.4	{ 846.6 ----- -----	{ 215. 197. 215.
C ₈ H ₁₀ -----	Dimethylmethylenecyclopropane.-----	82.08	34				
C ₈ H ₁₀ -----	Tetrahydrobenzene (cyclohexene).-----	82.08	34	{ 891.2 893.7 891.9	{ 3,727.0 3,743.7 3,732.6	{ 892.2 ----- -----	{ 215. 165. 197; cf. 91. ²⁷
C ₇ H ₁₂ -----	Methyl-1-cyclohexene-3-----	96.10	40	{ 1,043.6 1,040.9 1,048.1	{ 4,364.3 4,353.0 4,390.5	{ 1,048.5 1,048.5 -----	{ 215 215. 165; cf. 162.
C ₇ H ₁₂ -----	Methyl-1-cyclohexene-1-----	96.10	40				
C ₇ H ₁₂ -----	Methylenecyclohexane-----	96.10	40	{ 1,044.1 1,051.4 1,054.9	{ 4,366.4 4,404.2 4,414.8	{ 1,055.0 ----- -----	{ 215. 163. 91.
C ₇ H ₁₂ -----	Cycloheptene-----	96.10	40	1,049.9	4,390.7	1,048.5	215.
C ₈ H ₁₂ -----	1-Methyl-3-methylenecyclohexene-1.-----	108.10	44	1,149.2	4,814.0	1,165.7	162.
C ₈ H ₁₂ -----	1,3-Dimethyldihydrobenzene.-----	108.10	44	²⁸ 1,148.2	4,801.7	1,159.2	215.
C ₈ H ₁₂ -----	1,4-Dimethylcyclohexadiene-1,3.-----	108.10	44	1,152.2	4,826.6	1,159.2	165.
C ₈ H ₁₄ -----	Ethyl-1-cyclohexene-1-----	110.11	46	1,203.7	5,042.3	1,204.8	165; cf. 162.

²⁶ In the case of 1,4 conjugated systems, the correction factor for each double bond should be not 13, but a smaller value, say 6.5, in agreement with the lower reactivity of these compounds. It is, however, omitted here, for the data at hand do not allow one to draw far-reaching conclusions and are too conflicting.

²⁷ This author gives the heat of combustion of cyclohexene as 898.8 kg.-cal₁₅ Whether it is for constant volume or constant pressure he does not state, and he gives no experimental details of any kind except that he used the internationally accepted value for benzoic acid.

²⁸ Compare values obtained by (215) and (197) for dihydrobenzene.

VIII. TABLES OF DATA—Continued

1. CH COMPOUNDS—Continued

7. HYDROAROMATIC HYDROCARBONS—Continued

(Unsaturated)

$$Q = 26.05 \times N + 6.56$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₈ H ₁₄ -----	Ethylencyclohexane-----	110. 11	46	1, 207. 7	5, 059. 1	1, 211. 3	163; cf. 162.
C ₈ H ₁₄ -----	Laurolene-----	110. 11	46	1, 192. 7	4, 987. 9	1, 204. 8	215.
C ₈ H ₁₄ -----	<i>iso</i> -Laurolene (1,1,2-Trimethylcyclopentene-2).-----	110. 11	46	1, 193. 3	4, 990. 4	1, 204. 8	215.
C ₈ H ₁₄ -----	1,3-Dimethylcyclohexene-3.-----	110. 11	46	1, 194. 5	4, 995. 4	1, 204. 8	215.
C ₉ H ₁₄ -----	1-Methyl-4-ethylcyclohexadiene-1,3.-----	122. 11	50	1, 310. 8	5, 490. 9	1, 315. 5	165.
C ₉ H ₁₆ -----	Isopropyl-1-cyclohexene-1.-----	124. 13	52	1, 340. 8	5, 611. 2	1, 361. 1	168.
C ₁₀ H ₁₀ -----	Δ ₁ -Dihydronaphthalene-----	130. 08	50	{ 1, 296. 3 1, 312. 5	{ 5, 429. 2 5, 488. 9	{ 1, 302. 0 1, 302. 0	{ 165. 105.
C ₁₀ H ₁₀ -----	Δ ₂ -Dihydronaphthalene(s)-----	130. 08	50	{ 1, 298. 3 1, 339. 6	{ 5, 438. 6 5, 611. 6	{ 1, 302. 0 1, 347. 6	{ 165. 165.
C ₁₀ H ₁₂ -----	Tetrahydronaphthalene-----	132. 10	52	{ 1, 352. 4 1, 419. 3	{ 5, 655. 7 5, 935. 5	{ 1, 347. 6 1, 419. 7	{ 105. 105.
C ₁₀ H ₁₄ -----	Hexahydronaphthalene-----	134. 11	54	1, 419. 3	5, 935. 5	1, 419. 7	105.
C ₁₀ H ₁₆ -----	Octahydronaphthalene-----	136. 13	56	1, 461. 7	6, 114. 3	1, 465. 3	105.
C ₁₀ H ₁₆ -----	Isobutenyl-1-cyclohexene-1.-----	136. 13	56	1, 461. 8	6, 123. 5	1, 478. 3	167.
C ₁₀ H ₁₆ -----	1,5-dimethyl-3-vinylcyclohexene-1.-----	136. 13	56	1, 455. 7	6, 097. 9	1, 478. 3	176; cf. 162.
C ₁₀ H ₁₆ -----	1-Methyl-4-isopropylcyclohexadiene-1,3.-----	136. 13	56	1, 470. 7	6, 160. 8	1, 471. 8	165.
C ₁₀ H ₁₈ -----	1-Ethyl-5-dimethylcyclohexene-1.-----	138. 14	58	1, 504. 5	6, 302. 4	1, 517. 4	171.
C ₁₀ H ₁₈ -----	Menthene (Δ ₃ -Terpene)-----	138. 14	58	1, 523. 2	6, 374. 6	1, 517. 4	183.
C ₁₁ H ₁₈ -----	1,5-Dimethyl-3-isopropenecyclohexene-1.-----	150. 14	62	1, 615. 0	6, 765. 2	1, 634. 0	176.

8. TERPENES

$$Q = 26.05 \times N + 13c + 6.56$$

C ₁₀ H ₁₆ -----	<i>l</i> -Limonene-----	136. 13	56	1, 457. 2	6, 094. 0	1, 477. 5	215.
C ₁₀ H ₁₆ -----	<i>d</i> -Limonene-----	136. 13	56	1, 471. 2	6, 162. 9	1, 477. 5	7.
C ₁₀ H ₁₆ -----	<i>d</i> -“Citrene”-----	136. 13	56	1, 473. 0	6, 164. 5	-----	32.
C ₁₀ H ₁₆ -----	<i>d</i> -α-Pinene (Australene)-----	136. 13	56	1, 471. 9	6, 155. 5	1, 465. 3	215; cf. 7, 6.
C ₁₀ H ₁₆ -----	<i>l</i> -α-Pinene (Terebenthene)-----	136. 13	56	{ 1, 473. 2 1, 480. 5	{ 6, 160. 9 6, 195. 9	{ 1, 465. 3 -----	{ 215. 183; cf. 32.
C ₁₀ H ₁₆ -----	β-Pinylene-----	136. 13	56	1, 469. 3	6, 154. 9	-----	175.
C ₁₀ H ₁₆ -----	Sylvestrene-----	136. 13	56	1, 464. 7	6, 135. 6	1, 477. 5	6.
C ₁₀ H ₁₆ -----	Camphene(s) cryst.-----	136. 13	56	{ 1, 467. 6 1, 468. 8	{ 6, 147. 8 6, 144. 0	{ 1, 471. 8 -----	{ 6. 47.
C ₁₀ H ₁₆ -----	Terecamphene (<i>inact.</i>)-----	136. 13	56	1, 466. 7	6, 138. 1	1, 471. 8	183.
C ₁₀ H ₁₆ -----	Borneocamphene-----	136. 13	56	1, 470. 2	6, 152. 8	1, 471. 8	183.
C ₁₀ H ₁₆ -----	Cyclene(s) (Tricyclene)-----	136. 13	56	1, 467. 3	6, 146. 5	-----	175.
C ₁₀ H ₁₆ -----	α-Terpinene-----	136. 13	56	1, 470. 4	6, 159. 5	1, 471. 8	163.

9. ACETYLENE HYDROCARBONS

$$Q = 26.05 \times N + 33.1h + 46.1g$$

C ₂ H ₂ -----	Acetylene (g) (Ethine)-----	26. 02	10	²⁹ 312. 0	1, 304. 8	306. 1	137; cf. 223, 10.
C ₃ H ₄ -----	Allylene (g) (Propine)-----	40	16	{ 465. 1 473. 0	{ 1, 945. 5 1, 978. 6	462. 9	223. 37; cf. 103.
C ₆ H ₆ -----	Dipropargyl (v) (1,5-Hexadiene).-----	78	30	{ 853. 5 882. 9	{ 3, 570. 2 3, 694. 9	873. 7	12. 223.
C ₆ H ₆ -----	Dimethyldiacetylene (2,4-Hexadiene).-----	78. 05	30	847. 8	3, 546. 4	847. 7	122.
C ₇ H ₁₂ -----	Heptene-1.-----	96. 10	40	1, 091. 2	4, 564. 5	1, 088. 0	138.
C ₈ H ₆ -----	Phenylacetylene (Phenylethine).-----	102. 05	38	1, 024. 2	4, 284. 2	1, 029. 5	138.
C ₁₀ H ₁₀ -----	Phenyl-1-butene-3.-----	130. 08	50	1, 340. 0	5, 605. 2	1, 342. 1	138.
C ₁₀ H ₁₀ -----	Diphenyldiacetylene (s)-----	202. 08	74	1, 975. 6	8, 267. 9	1, 980. 9	172.

²⁹ The author (137) gives also the heat of explosion of acetylene.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS

10. PRIMARY ALCOHOLS

$$Q = 26.05 \times N + 13$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
CH ₄ O.....	Methyl alcohol.....	32.03	6	170.9	714.7	169.3	153; cf. 172, 191, 223.
C ₂ H ₅ O.....	Ethyl alcohol.....	46.05	12	{ 327.6 329.4	{ 1,370.0 1,378.5	325.6	153. 172; cf. 3, 64.
C ₃ H ₄ O.....	Propargyl alcohol (v).....	56.00	14	428.9	1,793.7	423.8	223.
C ₃ H ₅ O.....	Allyl alcohol.....	58.05	16	442.4	1,850.6	442.8	111.
C ₃ H ₅ O.....	n-Propyl alcohol.....	60.06	18	{ 483.5 480.5	{ 2,022.0 2,009.4	481.7	153. 215; cf. 110.
C ₄ H ₁₀ O.....	n-Butyl alcohol.....	74.08	24	{ 638.6 640.1	{ 2,674.4 2,678.8	638.2	215. 229; cf. 153.
C ₄ H ₁₀ O.....	Isobutyl alcohol (primary).....	74.08	24	638.2	2,668.9	638.2	153; cf. 215.
C ₅ H ₁₂ O.....	Amyl alcohol (?).....	88	30	787.3	3,293.3	65.	65.
C ₅ H ₁₂ O.....	Amyl alcohol (ferm.) ³⁰	88.10	30	{ 791.6 793.7	{ 3,310.5 3,320.1	794.5	215. 110.
C ₇ H ₁₆ O.....	n-Heptyl alcohol.....	116.13	42	{ 1,104.9 891.2	{ 4,620.7 3,727.9	1,107.1	215. 179.
C ₇ H ₈ O.....	Benzyl alcohol.....	108.06	34	{ 894.3 894.3	{ 3,742.7 3,742.7	895.2	182; cf. 205.
C ₈ H ₁₈ O.....	Octyl alcohol.....	130.14	48	1,262.0	5,278.9	1,263.4	115.
C ₈ H ₁₄ O.....	Amylpropargyl alcohol ³¹	126.11	44	1,191.9	4,984.5	1,192.3	138.
C ₉ H ₅ O.....	Phenylpropargyl alcohol ³²	132.06	42	1,137.3	4,757.33	1,133.7	138.
C ₉ H ₁₆ O.....	Hexylpropargyl alcohol.....	140.13	50	1,340.1	5,605.6	1,348.6	138.
C ₁₆ H ₃₁ O.....	Cetyl alcohol (s).....	242.27	96	2,504.5	10,481.3	2,513.8	181.

³⁰ Mostly isobutyl carbinol.³¹ C₈H₁₁.C≡C-CH₂OH.³² C₆H₅.C≡C-CH₂OH.11. PRIMARY ALCOHOLS (Cyclic)³³

$$Q = 26.05 \times N + 13$$

C ₅ H ₁₀ O.....	Cyclobutyl carbinol.....	86.08	28	747.8	3,127.3	742.4	215.
C ₇ H ₁₄ O.....	Cyclohexyl carbinol.....	114.11	40	1,047.2	4,379.4	1,055.0	215.

³³ Among the cyclic alcohols should be included cholesterol. However, it is omitted here because Berthelot and André, Ann. chim. phys., (7), 17, p. 433; 1899, who determined the heat of combustion of cholesterol, give for the formula of the compound C₂₆H₄₄O. The present accepted formula is C₂₇H₄₆O.

12. SECONDARY ALCOHOLS

$$Q = 26.05 \times N + 6.5$$

C ₃ H ₈ O.....	Isopropyl alcohol.....	60.06	18	474.8	1,985.6	475.4	215; cf. 110.
C ₃ H ₁₀ O.....	Ethylvinyl carbinol.....	86.08	28	752.9	3,148.6	748.9	111.
C ₆ H ₁₄ O.....	Pinacolyl alcohol.....	102.11	36	938.6	3,925.2	944.3	215.
C ₇ H ₁₆ O.....	Diallyl carbinol.....	112.10	38	1,023.2	4,299.9	1,022.4	215.
C ₁₃ H ₁₂ O.....	Diphenyl carbinol (s).....	184.10	62	1,615.4	6,760.5	1,614.6	182; cf. 179.
C ₁₄ H ₁₈ O.....	Amylphenylpropargyl alcohol ³⁴	202.14	72	1,901.1	7,910.4	1,921.7	138.
C ₅ H ₁₀ O ₂	Dimethylolcyclopropane.....	102.08	-----	707.6	2,959.2	-----	215.
C ₆ H ₁₂ O.....	β-Methylcyclopentanol.....	100.10	34	887.6	3,711.9	892.7	215.
C ₆ H ₁₂ O.....	Cyclohexanol.....	100.10	34	890.7	3,724.9	892.7	153; cf. 215.
C ₇ H ₁₄ O.....	1,3-Dimethylcyclopentanol-2.....	114.11	40	1,030.5	4,309.6	1,048.5	215.
C ₇ H ₁₄ O.....	Ethyl-1-cyclopentanol-2.....	114.11	40	1,039.0	4,345.1	1,048.5	215.
C ₇ H ₁₄ O.....	β-Methylcyclohexanol.....	114.11	40	1,038.4	4,342.6	1,048.5	215.
C ₇ H ₁₄ O.....	Cycloheptanol.....	114.11	40	1,050.2	4,391.9	1,048.5	215.
C ₈ H ₁₆ O.....	1-3-Dimethylcyclohexanol-2.....	128.13	46	1,196.0	5,001.7	1,204.8	215.
C ₈ H ₁₆ O.....	1,3-Dimethylcyclohexanol-5.....	128.13	46	1,183.4	4,949.0	1,204.8	215.
C ₉ H ₁₈ O.....	Cycloheptylmethyl carbinol.....	142.14	52	1,342.2	5,613.1	1,361.1	215.
C ₁₀ H ₁₈ O.....	Thujyl alcohol.....	154.14	56	1,477.5	6,189.3	-----	175.
C ₁₀ H ₁₈ O.....	Borneol (Borneo camphor).....	154.14	56	³⁵ 1,469.6	6,145.9	1,465.3	125.
C ₁₀ H ₁₈ O.....	Borneol (synthetic).....	154.14	56	1,466.2	6,136.1	1,465.3	183; cf. 125
C ₁₀ H ₁₈ O.....	d-Borneol (s).....	154.14	56	1,466.6	6,131.9	1,465.3	89.
C ₁₀ H ₁₈ O.....	l-Borneol.....	154.14	56	1,467.2	6,134.4	1,465.3	89.
C ₁₀ H ₂₀ O.....	Menthol (s).....	156.16	58	1,508.8	6,309.8	1,517.4	113.

³⁴ C₆H₁₁C≡C-CH(OH)(C₆H₅).³⁵ Mean value.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

13. HYDROAROMATIC AND POLYMETHYLENE SECONDARY ALCOHOLS

$$Q = 26.05 \times N + 6.5$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kil-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₆ H ₁₂ O ₅ -----	Quercitol (s)-----	164.10	26	704.2	2,947.1	-----	195.
C ₆ H ₁₂ O ₆ -----	Inositol (s) (Inosite)-----	180.10	24	662.1	2,770.9	-----	195.

14. TERTIARY ALCOHOLS

$$Q = 26.05 \times N + 3.5$$

C ₄ H ₁₀ O-----	Trimethyl carbinol (<i>Tert.</i> butyl alcohol)-----	74.08	24	629.3	2,631.7	628.7	215; cf. 115.
C ₅ H ₁₂ O-----	Dimethylethyl carbinol-----	88.10	30	784.6	3,281.2	785.0	215; cf. 110.
C ₆ H ₁₄ O-----	Allyldimethyl carbinol-----	100.10	34	886.5	3,707.3	902.2	215.
C ₆ H ₁₄ O-----	Methyldiethyl carbinol-----	102.11	36	913.7	3,821.1	-----	113.
				927.0	3,876.7	941.3	215.
C ₇ H ₁₆ O-----	Allylmethylethyl carbinol-----	114.11	40	1,050.1	4,391.5	1,058.5	215.
C ₇ H ₁₆ O-----	Triethyl carbinol-----	116.13	42	1,080.0	4,516.6	1,097.6	215.
C ₈ H ₁₈ O-----	Diallylmethyl carbinol-----	126.11	44	1,180.7	4,937.7	1,175.7	215; cf. 113.
C ₈ H ₁₈ O-----	Allylmethylpropyl carbinol-----	128.13	46	1,201.9	5,026.4	1,214.8	215.
C ₈ H ₁₈ O-----	Allyldiethyl carbinol-----	128.13	46	1,207.1	5,048.1	1,214.8	215.
C ₈ H ₁₈ O-----	Methyldipropyl carbinol-----	130.14	48	1,232.7	5,155.2	1,253.9	215.
C ₈ H ₁₈ O-----	Allylmethyl- <i>n</i> -butyl carbinol-----	142.14	52	1,364.9	5,708.0	1,371.1	215.
C ₈ H ₁₈ O-----	Allylmethyl- <i>tert.</i> -butyl carbinol-----	142.14	52	1,363.0	5,700.0	1,371.1	215.
C ₈ H ₂₀ O-----	Ethylidipropyl carbinol-----	144.16	54	1,386.5	5,798.3	1,410.2	215.
C ₁₀ H ₁₈ O-----	Diallylpropyl carbinol-----	154.14	56	1,472.1	6,156.3	1,488.3	215.
C ₁₀ H ₂₀ O-----	Allyldipropyl carbinol-----	156.16	58	1,518.0	6,348.3	1,527.4	215.
				1,549.6	6,480.4	-----	113.
C ₁₁ H ₂₂ O-----	Allylmethylhexyl carbinol-----	170.18	64	1,666.7	6,970.1	1,683.7	215.
C ₁₀ H ₁₈ O-----	Triphenyl carbinol (s)-----	260.13	90	2,340.8	9,796.3	2,337.5	182; cf. 179.
C ₂₁ H ₁₆ O-----	Diphenylphenylethynyl carbinol. ³⁶ -----	284.12	98	2,572.3	10,757.4	2,576.0	95.
C ₇ H ₁₄ O-----	1,3-Dimethylcyclopentanol-3-----	114.11	40	1,034.0	4,324.2	1,045.7	215.
C ₈ H ₁₆ O-----	1,2-Dimethylcyclohexanol-2-----	128.13	46	1,196.5	5,012.1	1,201.8	163.
C ₈ H ₁₆ O-----	1,3-Dimethylcyclohexanol-3-----	128.13	46	1,192.5	4,987.0	1,201.8	215.
C ₈ H ₁₆ O-----	1,3,5-Trimethylcyclohexene-6-ol-5-----	140.13	50	1,294.7	5,414.4	1,312.5	215.
C ₈ H ₁₈ O-----	1-Methyl-3-ethylcyclohexanol-3-----	142.14	52	1,322.4	5,530.3	1,358.1	215.
C ₁₀ H ₁₈ O-----	Terpineol (s)-----	154.14	56	1,469.5 up to 1,480.0	6,145.4 6,189.4	1,468.8	125.
C ₁₀ H ₂₂ O ₃ -----	Terpine hydrate (s)-----	190.18	56	1,451.0	6,068.1	-----	125.

³⁶ (C₆H₅)₂ :—C≡C—C₆H₅.
OH

15. POLYHYDROXY ALIPHATIC ALCOHOLS

$$Q = 26.05 \times N + 13j + 6.5k + 3.5l$$

C ₂ H ₆ O ₂ -----	Ethylene glycol ³⁷ -----	62.05	10	281.9	1,179.8	286.5	195; cf. 109.
C ₃ H ₈ O ₂ -----	Propylene glycol-----	76.06	16	431.0	1,802.4	436.3	111.
C ₃ H ₈ O ₂ -----	Isopropylene glycol-----	76.06	16	436.1	1,823.8	442.8	111.
C ₄ H ₈ O ₃ -----	Glycerol-----	92.06	14	397.0	1,661.5	397.2	195; cf. 181, 64.
C ₄ H ₁₀ O ₄ -----	Erythritol (s)-----	122.08	18	504.1	2,109.7	507.9	182; cf. 126, 31.
C ₅ H ₁₂ O ₄ -----	Pentaerythritol (s)-----	136.10	24	661.2	2,767.1	657.7	195.
C ₆ H ₁₄ O ₃ -----	Arabitol (s)-----	152.10	22	611.8	2,560.4	618.6	195.
C ₆ H ₁₄ O ₂ -----	Pinacol (s) (Tetramethylethylene glycol)-----	118.11	34	897.6	3,753.8	898.7	115.

³⁷ The heat of combustion of diethylene glycol, HO—CH₂.CH₂.O—CH₂.CH₂.OH (liq.), is given by Wm. H. Rinkenbach (156) as 566.7 kg.-cal₁₅ per mole. No experimental details as to procedure employed are given.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

15. POLYHYDROXY ALIPHATIC ALCOHOLS—Continued

$$Q = 26.05 \times N + 13j + 6.5k + 3.5l$$

Formula	Name	Molec- ular weight	Num- ber of elec- trons (<i>N</i>)	Kg-cal ₁₅ (exper- imental)	Kilo- joules (K. J.)	Kg-cal ₁₅ (calcu- lated to the liquid state)	Literature
C ₆ H ₁₄ O ₆ -----	<i>d</i> -Mannitol (s)-----	182.11	26	727.6	3,045.0	729.4	195; cf. 182.
C ₆ H ₁₄ O ₆ -----	Dulcitol (s)-----	182.11	26	729.1	3,049.1	729.4	48.
C ₇ H ₁₆ O ₇ -----	Perseitol (Glucoheptol) (s) (<i>d</i> -mannoheptol).	212.13	30	723.7	3,028.7	-----	195.
C ₈ H ₁₈ O ₈ -----	Tetramethylbutenediol-----	142.11	42	835.8	3,497.8	840.0	195; cf. 68.
C ₈ H ₁₆ O ₂ -----	Tetramethylbutenediol (s) (Maleinoid).	144.13	44	1,142.3	4,780.5	1,134.2	173.
C ₈ H ₁₆ O ₂ -----	Tetramethylbutenediol (s) (Fumaroid).	144.13	44	1,172.3	4,906.1	1,166.2	173.
C ₁₄ H ₁₄ O ₂ -----	Hydrobenzoin (s) ³⁸ -----	214.11	66	1,175.7	4,920.3	1,166.2	173.
C ₁₄ H ₁₄ O ₂ -----	Isobenzoin (s) ³⁸ -----	214.11	66	1,723.0	7,210.8	1,725.3	10.
C ₁₄ H ₁₄ O ₂ -----	Isobenzoin (s) ³⁸ -----	214.11	66	1,727.8	7,230.8	1,725.3	10.

³⁸ The form used is not indicated. See, however, Erlenmeyer, jr., Ber., 30, p. 1537; 1897.

16. HYDROAROMATIC AND POLYMETHYLENE GLYCOLS

(All types)

$$Q = 26.05 \times N + 13j + 6.5k + 3.5l$$

C ₅ H ₁₀ O ₂ -----	Cyclopentenediol-1,2 (<i>cis</i>). ³⁹	102.08	26	696.1	2,913.2	690.3	237.
C ₅ H ₁₀ O ₂ -----	Cyclopentenediol-1,2 (<i>trans</i>).	102.08	26	694.2	2,905.2	690.3	237.
C ₆ H ₁₂ O ₂ -----	Cyclohexanediol-1,2 (<i>cis</i>)-----	116.09	32	841.6	3,522.1	846.3	237.
C ₆ H ₁₂ O ₂ -----	Cyclohexanediol-1,2 (<i>trans</i>)-----	116.09	32	842.7	3,526.7	846.3	237.
C ₇ H ₁₄ O ₂ -----	1-Methylcyclohexane-1,2- diol (<i>cis</i>).	130.11	38	992.6	4,154.0	999.9	237.
C ₇ H ₁₄ O ₂ -----	1-Methylcyclohexane-1,2- diol (<i>trans</i>).	130.11	38	995.1	4,164.5	999.9	237.
C ₉ H ₁₈ O ₂ -----	Hydrindene-1,2-diol (<i>cis</i>)-----	150.08	42	1,098.5	4,597.2	1,100.1	237.
C ₉ H ₁₈ O ₂ -----	Hydrindene-1,2-diol (<i>trans</i>)-----	150.08	42	1,096.7	4,589.7	1,100.1	237.
C ₁₀ H ₁₂ O ₂ -----	1,2,3,4-Tetrahydronaphtha- lene-1,2-diol (<i>cis</i>).	164.09	48	1,250.7	5,234.2	1,256.4	237.
C ₁₀ H ₁₂ O ₂ -----	1,2,3,4-Tetrahydronaphtha- lene-1,2-diol (<i>trans</i>).	164.09	48	1,249.4	5,228.7	1,256.4	237.
C ₁₀ H ₁₂ O ₂ -----	1,2,3,4-Tetrahydronaphtha- lene-2,3-diol (<i>cis</i>).	164.09	48	1,250.9	5,235.0	1,256.4	237.
C ₁₀ H ₁₂ O ₂ -----	1,2,3,4-Tetrahydronaphtha- lene-2,3-diol (<i>trans</i>).	164.09	48	1,249.4	5,228.7	1,256.4	237.
C ₁₂ H ₁₈ O ₂ -----	1-Phenylcyclohexane-1,2- diol (<i>cis</i>).	192.12	60	1,563.1	6,541.6	1,569.5	237.
C ₁₂ H ₁₈ O ₂ -----	1-Phenylcyclohexane-1,2- diol (<i>trans</i>).	192.12	60	1,564.9	6,549.1	1,569.5	237.

³⁹ The heats of combustion of the acetates and benzoates of these compounds are given below (observer 237):

	<i>Cis.</i>		<i>Trans.</i>	
	Kg-cal ₁₅	Kilo- joules	Kg-cal ₁₅	Kilo- joules
1. Cyclopentane-1,2 diacetate (liq.)-----	1,114.7	4,665.0	1,114.1	4,662.5
2. Cyclopentane-1,2 dibenzoate (s)-----	2,242.5	9,384.9	2,240.3	9,375.7
3. Cyclohexane-1,2 diacetate (liq.)-----	1,261.6	5,279.8	1,263.4	5,287.3
4. Cyclohexane-1,2 dibenzoate (s)-----	2,392.6	10,013.0	2,388.7	9,996.7
5. 1-Methylcyclohexane-1,2 dibenzoate-----	-----	-----	2,545.1	10,651.2
6. Hydrindene-1,2 diacetate-----	1,515.8 (s)	6,343.6	1,519.3 (liq.)	6,358.3
7. Hydrindene-1,2 dibenzoate-----	2,645.3	11,070.6	2,647.1	11,078.1
8. Tetrahydronaphthalene-1,2 diacetate (s)-----	-----	-----	1,667.0	6,976.4
9. Tetrahydronaphthalene-1,2 dibenzoate-----	-----	-----	2,798.1	11,710.1
10. Tetrahydronaphthalene-2,3 dibenzoate-----	2,797.8	11,708.8	2,799.6	11,716.3

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

17. PHENOLS

$$Q = 26.05 \times N + 3.5 - 3.5a - 6.5b$$

Formula	Name	Molecular weight	Number of electrons (<i>N</i>)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₆ H ₆ O-----	Phenol (s)-----	94.05	28	732.2	3,064.3	732.9	195; cf. 30.
C ₆ H ₆ O ₂ -----	Pyrocatechol (s)-----	110.05	26	684.8	2,865.9	684.3	195.
C ₆ H ₆ O ₂ -----	Resorcinol (s)-----	110.05	26	683.0	2,858.4	684.3	195.
C ₆ H ₆ O ₂ -----	Hydroquinol (s)-----	110.05	26	682.9	2,857.9	684.3	195.
				683.7	2,859.2	-----	225; cf. 30, 180.
C ₆ H ₆ O ₃ -----	Pyrogallol (s)-----	126.05	24	638.7	2,672.9	635.7	195; cf. 30.
C ₆ H ₆ O ₃ -----	Phloroglucinol (s)-----	126.05	24	⁴⁰ 617.3	2,583.4	635.7	202.
C ₇ H ₈ O-----	<i>o</i> -Cresol-----	108.06	34	⁴¹ 882.6	3,693.7	885.7	201.
	<i>o</i> -Cresol (s)-----	108.06	34	879.5	3,680.7	-----	201.
C ₇ H ₈ O-----	<i>m</i> -Cresol-----	108.06	34	880.5	3,684.9	885.7	201.
				895.1	⁴² 3,746.0	-----	211.
C ₇ H ₈ O-----	<i>p</i> -Cresol ⁴³ -----	108.06	34	882.5	3,693.3	885.7	211.
C ₇ H ₈ O-----	<i>p</i> -Cresol (s)-----	108.06	34	880.0	3,682.8	-----	211.
C ₇ H ₈ O ₂ -----	Orcinol (s)-----	124.06	32	824.3	3,449.7	837.1	201.
C ₇ H ₈ O ₂ -----	Saligenin (s)-----	124.06	32	845.4	3,535.5	846.6	44.
C ₇ H ₈ O ₂ -----	Toluhydroquinol (s)-----	124.06	32	835.1	3,494.9	837.1	225.
C ₈ H ₁₀ O-----	<i>o</i> -Xylenol (s)-----	122.08	40	1,035.1	4,331.9	1,038.5	201.
C ₈ H ₁₀ O-----	<i>m</i> -Xylenol (s)-----	122.08	40	1,037.4	4,341.5	1,038.5	201.
C ₈ H ₁₀ O-----	<i>p</i> -Xylenol (s)-----	122.08	40	1,035.3	4,332.7	1,038.5	201.
C ₉ H ₁₂ O-----	Pseudocumenol (s)-----	136.10	46	1,191.2	4,985.2	1,191.3	201.
C ₁₀ H ₈ O-----	α -Naphthol (s)-----	144.06	46	1,185.4	4,960.9	1,188.8	225.
C ₁₀ H ₈ O-----	β -Naphthol (s)-----	144.06	46	1,187.2	4,968.4	1,188.8	225.
C ₁₀ H ₁₄ O-----	Thymol-----	150.11	52	1,353.4	5,663.9	1,351.1	201.
	Thymol (s)-----			1,349.7	5,648.5	-----	201.
C ₁₀ H ₁₄ O-----	Carvacrol-----	150.11	52	1,354.5	5,668.6	1,351.1	201.
C ₁₀ H ₁₄ O ₂ -----	Thymohydroquinol (s)-----	166.11	50	1,307.1	5,470.2	1,302.5	225.
C ₁₄ H ₁₀ O ₂ -----	Phenanthrahydroquinol (s)-----	210.08	62	1,600.1	6,696.4	1,602.6	225.
C ₂₁ H ₁₆ O ₂ -----	β -Dioxynaphthylmethane (s)-----	300.13	96	2,475.8	10,353.8	2,474.8	60.

⁴⁰ The determinations by (202) were carried out in oxygen at ordinary pressure and differ greatly from later determinations by (195). Thus, (202) give for pyrogallol 616.3 kg-cal₁₅, but (195) give 639.0 kg-cal₁₅ per mole. The above value for phloroglucinol is undoubtedly very low. It should be approximately the same as that for pyrogallol.

⁴¹ It is quite possible that the same objection and the inherent error in the determinations occur also in the values of (201) as occur in (202). See footnote 40.

⁴² This value is undoubtedly too high.

⁴³ M. F. Barker, J. Phys. Chem. **29**, p. 1350, 1925, reports the following values for the three cresols at constant pressure: *o*-(s), 883.7; *p*-(s), 885.0; *m*-(liq.), 883.0. However, no experimental details are available except the final values.

18. ALIPHATIC ETHERS ⁴⁴

$$Q = 26.05 \times N + 19.5$$

C ₂ H ₆ O-----	Dimethyl ether (g)-----	46	12	347.6	1,453.7	-----	223; cf. 10.
C ₃ H ₈ O-----	Methylethyl ether (v)-----	60	18	503.4	2,105.2	-----	223.
C ₄ H ₁₀ O-----	Methylpropargyl ether (v)-----	70.00	20	600.8	2,512.6	-----	223.
C ₄ H ₁₀ O-----	Methyldiallyl ether (v)-----	72.00	22	623.9	2,609.2	-----	223.
C ₄ H ₁₀ O-----	Diethyl ether-----	74.08	24	651.7	2,727.4	-----	204.
	Diethyl ether (v)-----			660.3	2,763.4	-----	204.
C ₆ H ₁₀ O-----	Diallyl ether (v)-----	98	32	906.6	3,791.4	-----	223.
C ₈ H ₁₀ O ₂ -----	Acetylacetone- <i>O</i> -methyl ether-----	114.08	30	817.8	3,422.5	820.5	166.
C ₈ H ₁₄ O ₂ -----	Glycoldiethyl ether-----	118.11	34	924.6	3,869.5	924.7	172.
C ₇ H ₁₂ O ₂ -----	Acetylacetone- <i>O</i> -ethyl ether-----	128.10	36	968.0	4,051.1	976.8	166.
C ₁₀ H ₂₂ O-----	Diamyl ether-----	158.17	60	1,609.3	6,730.1	1,582.0	65.

⁴⁴ For heat of combustion of diethylene glycol, see footnote (37), p. 380.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

19. ALIPHATIC ACETALS⁴⁵

$$Q = 26.05 \times N + 19.5 \times O$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₃ H ₆ O ₂ -----	Glycolmethyal (Methylene-ethylene dioxide).	74.05	14	409.9	1,715.43	403.7	59.
C ₃ H ₈ O ₂ -----	Methyal.	76.06	16	462.8	1,936.8	455.8	26.
C ₄ H ₈ O ₂ -----	Glycolacetal (Ethylidene-acetal of glycol).	88.06	20	559.2	2,340.3	560.1	59.
C ₄ H ₁₀ O ₂ -----	Dimethylacetal.	90.09	22	620.0	2,594.7	612.1	58.
C ₄ H ₁₀ O ₃ -----	Methyl orthoformate (v).	106.0	20	⁴⁶ 596.8	2,495.8	579.5	223.
C ₅ H ₁₂ O ₂ -----	Diethylmethyal.	104.10	28	$\left\{ \begin{array}{l} 774.5 \\ 47 \text{ } 773.8 \end{array} \right.$	$\left\{ \begin{array}{l} 3,241.3 \\ 3,238.4 \end{array} \right.$	768.2	58. 103.
C ₆ H ₁₄ O ₂ -----	Diethylacetal.	118.11	34	$\left\{ \begin{array}{l} 923.0 \\ 931.2 \\ 919.5 \end{array} \right.$	$\left\{ \begin{array}{l} 3,862.8 \\ 3,897.1 \\ 3,848.1 \end{array} \right.$	924.7	157. 58. 117.
C ₆ H ₁₀ O ₄ -----	Erythritemethyal (s).	146.08	26	745.0	3,117.8	-----	59.
C ₇ H ₁₆ O ₂ -----	Dipropylmethyal.	132.13	40	1,085.9	4,544.5	1,081.1	58.
C ₇ H ₁₄ O ₆ -----	α-Methylglycoside (s).	194.11	30	842.5	3,529.2	-----	241.
C ₈ H ₁₄ O ₄ -----	Erythritediactal (s).	174.11	38	1,049.5	4,392.2	1,067.9	59.
C ₉ H ₂₀ O ₂ -----	Diisobutylmethyal.	160.16	52	1,395.3	5,839.3	1,393.6	58.
C ₉ H ₁₄ O ₆ -----	Mannitotrimethyal (s).	218.11	38	1,084.1	4,536.9	1,074.4	59.
C ₁₁ H ₂₄ O ₂ -----	Diisoamylmethyal.	188.19	64	1,708.7	7,150.9	1,706.2	58.
C ₁₂ H ₂₀ O ₆ -----	Mannitetriactal (s).	260.16	56	1,539.0	6,440.7	-----	59.
C ₁₂ H ₂₂ O ₂ -----	Amylpropionic acetal.	198.18	66	1,790.7	7,494.1	1,791.4	138.
C ₁₂ H ₂₂ O ₄ -----	Diactal of acetylenedialdehyde (s). ⁴⁸	230.17	62	1,724.9	7,218.7	1,726.4	138.
C ₁₃ H ₂₄ O ₂ -----	Hexylpropionic acetal.	212.19	72	1,946.4	8,145.7	1,947.7	138.

⁴⁵ The values for acetals given by (58 and 59) are about 0.5 per cent to 1.0 per cent too high.⁴⁶ Individual determinations do not agree better than 0.5 per cent.⁴⁷ The values of (103) are about 0.6 per cent too high. Better value, 769.2 kg-cal₁₅.⁴⁸ (C₂H₅O)₂: $\overset{\text{H}}{\text{C}} - \text{C} \equiv \text{C} - \overset{\text{H}}{\text{C}} : (\text{OC}_2\text{H}_5)_2$.

20. AROMATIC ETHERS

$$Q = 26.05 \times N + 19.5$$

C ₇ H ₈ O-----	Anisole.	108.06	34	$\left\{ \begin{array}{l} 905.1 \\ 900.9 \end{array} \right.$	$\left\{ \begin{array}{l} 3,787.8 \\ 3,770.3 \end{array} \right.$	905.2	196. 203.
C ₈ H ₁₀ O-----	Phenetole.	122.08	40	$\left\{ \begin{array}{l} 1,056.9 \\ 1,060.3 \end{array} \right.$	$\left\{ \begin{array}{l} 4,423.1 \\ 4,437.4 \end{array} \right.$	1,061.5	203. 211.
C ₈ H ₁₀ O-----	<i>m</i> -Cresolmethylether.	122.08	40	1,057.0	4,423.6	1,058.5	203.
C ₈ H ₁₀ O ₂ -----	Hydroquinoldimethyl ether (s).	138.08	38	1,014.7	4,246.5	1,028.9	203.
C ₈ H ₁₀ O ₂ -----	Resorcinoldimethyl ether.	138.08	38	1,022.6	4,279.6	1,028.9	203.
C ₈ H ₁₂ O-----	Phenylpropyl ether.	136.10	46	1,213.1	5,076.8	1,217.8	203.
C ₈ H ₁₂ O-----	<i>p</i> -Cresolethyl ether.	136.10	46	1,212.8	5,075.6	1,214.3	203.
C ₈ H ₁₂ O-----	<i>m</i> -Xylenolmethylether.	136.10	46	1,213.4	5,078.1	1,210.8	203.
C ₁₀ H ₁₆ O ₂ -----	Safrrole.	162.08	46	1,244.1	5,206.6	1,246.8	196.
C ₁₀ H ₁₆ O ₂ -----	Isosafrole.	162.08	46	1,233.9	5,163.9	1,243.8	196.
C ₁₀ H ₁₂ O-----	Methylchavicol (p-Allylanisole).	148.10	50	1,334.6	5,535.3	1,331.5	196.
C ₁₀ H ₁₂ O-----	Anethole (s).	148.10	50	1,324.4	5,542.6	1,331.5	196.
C ₁₀ H ₁₂ O-----	α-Ethoxystyrene.	148.10	50	1,314.7	5,507.3	1,328.5	163.
C ₁₀ H ₁₂ O ₂ -----	Eugenol.	164.10	48	1,286.6	5,384.4	1,282.9	196.
C ₁₀ H ₁₂ O ₂ -----	Isoeugenol.	164.10	48	1,277.6	5,346.8	1,279.9	196.
C ₁₀ H ₁₂ O ₂ -----	Allyl-3,4-guaiacol (Betelphenol).	164.10	48	1,286.4	5,383.6	1,282.9	196.
C ₁₀ H ₁₄ O-----	<i>p</i> -Xylenolethyl ether.	150.11	52	1,368.6	5,727.6	1,366.1	203.
C ₁₁ H ₁₄ O ₂ -----	Methyleugenol.	178.11	54	1,458.6	6,104.2	1,455.2	196.
C ₁₁ H ₁₄ O ₂ -----	Methylisoeugenol.	178.11	54	1,447.4	6,057.4	1,452.2	196.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

20. AROMATIC ETHERS—Continued

$$Q = 20.05 \times N + 19.5$$

Formula	Name	Molecular weight	Number of electrons (<i>N</i>)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₁₁ H ₁₆ O-----	Thymolmethyl ether-----	164.13	58	1,524.3	6,379.2	1,523.4	203.
C ₁₂ H ₁₄ O ₄ -----	Apiole (s)-----	222.11	54	1,498.8	6,272.5	1,494.2	196.
C ₁₂ H ₁₄ O ₄ -----	Isoapiole (s)-----	222.11	54	1,488.2	6,228.1	1,491.2	196.
C ₁₂ H ₁₆ O ₂ -----	Ethylisoegenol (s)-----	192.13	60	1,602.3	6,705.6	1,608.5	196.
C ₁₂ H ₁₆ O ₃ -----	Asarone(s) ⁴⁹ (Propenyl-2,4,5-trimethoxybenzene).	208.13	58	1,576.2	6,596.4	1,575.9	196.
C ₁₂ H ₁₈ O-----	Thymolethyl ether-----	178.14	64	1,679.9	7,030.4	1,679.7	203.
C ₁₆ H ₁₆ O ₂ -----	Di- <i>p</i> -methoxystilbene (s)-----	240.14	76	2,016.6	8,433.4	2,018.8	104.
C ₂₁ H ₁₆ O ₂ -----	β-Naphtholformal (s)-----	300.13	96	2,500.5	10,457.1	2,513.8	60.
C ₂₂ H ₁₈ O-----	Methyl ether of diphenylphenylethynyl carbinol. ⁵⁰	298.14	104	2,739.4	11,456.2	2,748.3	95.
C ₂₃ H ₂₀ O-----	Ethyl ether of diphenylphenylethynyl carbinol.	312.16	110	2,891.4	12,091.8	2,904.6	95.
C ₂₄ H ₂₂ O-----	Propyl ether of diphenylphenylethynyl carbinol.	326.17	116	3,047.5	12,744.7	3,060.9	95.

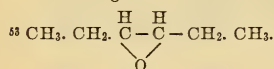
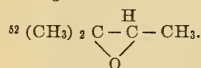
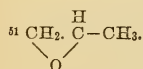
⁴⁹ (CH₃O)₃C(2,4,5)(C₆H₂)(CH=CH.CH₃)(1).

⁵⁰ (C₆H₅)₂C(OCH₃)C≡C.C₆H₅.

21. ETHYLENE OXIDES

(α-Oxides)

C ₂ H ₄ O-----	{Ethylene oxide (v)-----	44.03	10	308.4	1,290.7	-----	16; cf. 223.
	{Ethylene oxide-----			302.1	1,264.3	-----	16.
C ₃ H ₆ O-----	α-Propylene oxide ⁵¹ -----	58.05	16	451.1	1,887.9	-----	245.
C ₃ H ₁₀ O-----	β-Methyl-β, γ-butene oxide	86.08	28	749.8	3,137.9	-----	245.
	(α-Dimethyltrimethylene oxide). ⁵²						
C ₆ H ₁₂ O-----	γ,δ-Hexylene oxide ⁵³ -----	100.10	34	913.9	3,824.7	-----	245.
C ₉ H ₈ O-----	Indene oxide-----	132.06	42	1,116.8	4,673.8	-----	236.



22. ALIPHATIC ALDEHYDES

[Also those aromatic aldehydes in which the aldehyde group is not attached to the aromatic nucleus]

$$Q = 26.05 \times N + 13.0$$

CH ₂ O-----	Formaldehyde (g)-----	30.02	-----	134.1	561.2	-----	239.
$\frac{1}{n}$ (CH ₂ O) _n -----	Paraformaldehyde (c)-----			⁵⁴ 122.1	511.0	-----	239; cf. 56.
$\frac{1}{3}$ (CH ₂ O) ₃ -----	α-Trioxymethylene (s)-----			⁵⁴ 109.5	458.3	-----	239; cf. 56.
C ₂ H ₄ O-----	Acetaldehyde (v)-----	44	10	280.5	1,173.1	279.5	223; cf. 39.
C ₂ H ₄ O-----	Acetaldehyde-----	44.03	10	279.0	1,166.8	273.5	25.
C ₂ H ₂ O ₂ -----	Glyoxal (s)-----	58.02	6	172.3	720.6	182.3	69.
C ₃ H ₆ O-----	Propionaldehyde (v)-----	58	-----	438.4	1,833.4	429.8	223.
C ₃ H ₆ O-----	Propionaldehyde-----	58.05	16	434.2	1,815.8	429.8	25.

⁵⁴ No great reliance can be put upon the above values until the exact details of the determinations become available. The information in the article is extremely meager and insufficient.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

22. ALIPHATIC ALDEHYDES—Continued

[Also those aromatic aldehydes in which the aldehyde group is not attached to the aromatic nucleus]

$$Q = 26.05 \times N + 13.0$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₃ H ₄ O	Acrolein	56.03	14	{ 389.6 393.4	{ 1,629.3 1,646.4	390.7	{ 141. 238.
(C ₃ H ₄ O) ₃	Metaacrolein (s)	168.09	-----	1,168.8	4,891.4	-----	238.
C ₄ H ₆ O	Crotonaldehyde	70.05	20	542.1	2,267.1	547.0	117.
C ₄ H ₈ O	Isobutyraldehyde (v)	72	22	596.8	2,495.8	586.1	223.
C ₄ H ₈ O ₂	β-Hydroxybutyraldehyde (Aldol)	88.06	20	546.6	2,285.9	540.5	118.
C ₅ H ₁₀ O	Valeraldehyde	86.08	28	742.0	3,103.0	742.4	113.
C ₅ H ₄ O ₂	Furol (Furfuraldehyde)	96.03	20	559.5	2,339.8	-----	44.
C ₆ H ₁₂ O ₂	Paraldehyde	132.10	-----	812.8	3,399.1	-----	118.
(C ₂ H ₄ O) ₃	{ Metaldehyde (s) Metaldehyde	{ 132.10 -----	-----	{ 805.6 814.0	{ 3,371.4 3,406.6	-----	{ 126. 126.
C ₇ H ₁₄ O	n-Heptaldehyde (Oenanthol)	114.11	40	1,062.4	4,442.9	1,055.0	110.
C ₈ H ₈ O	Phenylpropionic aldehyde	130.05	40	1,081.0	4,520.7	1,081.6	138.
C ₉ H ₈ O	Cinnamic aldehyde	132.06	42	1,112.3	4,655.0	1,113.6	183.
C ₁₀ H ₁₆ O	Citral (Geranial)	152.13	54	1,437.0	6,019.6	1,445.7	174.

23. AROMATIC ALDEHYDES

$$Q = 26.05 \times N + 13 - 3.5a + 3.5m$$

C ₇ H ₆ O	Benzaldehyde	106.05	32	841.3	3,520.8	843.1	205.
C ₇ H ₆ O ₂	o-Hydroxybenzaldehyde (Salicylaldehyde)	122.05	30	796.0	3,328.9	794.5	62.
C ₇ H ₆ O ₂	p-Hydroxybenzaldehyde (s)	122.05	30	792.7	3,315.0	794.5	62.
C ₇ H ₆ O ₂	m-Hydroxybenzaldehyde (s)	122.05	30	788.7	3,303.9	794.5	163.
C ₈ H ₈ O ₃	Vanillin (s) (3-Methoxy-4-hydroxybenzaldehyde)	152.06	34	914.1	3,825.5	918.2	183.
C ₈ H ₆ O ₃	Piperonal (s) (Methyleneprotocatechuic aldehyde)	{ 150.05	32	{ 870.1 870.7	{ 3,641.4 3,647.4	882.1	{ 183. 163.
C ₁₄ H ₁₀ O ₃	Disalicylic aldehyde (s)	226.08	-----	1,589.0	6,645.2	-----	157.

24. ALIPHATIC KETONES

[Also those ketones in which the ketone group is not attached to the aromatic nucleus]

$$Q = 26.05 \times N + 6.5$$

C ₃ H ₆ O	Acetone (v)	58	16	435.8	1,822.5	-----	223.
C ₃ H ₆ O	Acetone	58.05	16	{ 430.8 426.8	{ 1,801.2 1,784.9	423.3	{ 64. 59.
C ₄ H ₈ O	Methyl ethyl ketone	72.06	22	582.3	2,435.2	579.6	215.
C ₄ H ₈ O ₂	Diacetyl ⁵⁵	86.05	18	503.3	2,104.8	-----	94.
C ₅ H ₈ O ₂	Acetylacetone ⁵⁶	100.06	24	⁵⁷ 615.9	2,575.7	638.2	78.
C ₅ H ₁₀ O	Diethyl ketone	86.08	28	735.6	3,076.3	735.6	215; cf. 116.
C ₅ H ₁₀ O	Methyl propyl ketone (v)	86	28	750.4	3,138.2	-----	223.
C ₅ H ₁₀ O	Methyl propyl ketone	86.08	28	735.6	3,076.3	735.6	215.
C ₅ H ₁₀ O	Methyl isopropyl ketone	86.08	28	733.9	3,069.2	735.6	215.
C ₆ H ₁₀ O	Ethyl allyl ketone	98.08	32	857.1	3,590.4	853.1	162.
C ₆ H ₁₀ O	Mesityl oxide	98.08	32	846.7	3,543.4	853.1	117.
C ₆ H ₁₀ O	Allylacetone	98.08	32	856.7	3,588.7	866.1	162.
C ₆ H ₁₀ O ₂	{ Methylacetylacetone After several distillations	{ 114.08 -----	{ 30 -----	{ 798.5 792.6	{ 3,341.7 3,317.0	794.5	{ 166. -----
C ₆ H ₁₂ O	Pinacolin (s) (Methyl tert-butyl ketone)	100.10	34	891.8	3,729.5	892.2	215.
C ₆ H ₁₂ O	Methyl butyl ketone	100.10	34	895.2	3,743.7	892.2	215.

⁵⁵ The author (94) gives only the final value for this compound, and no other information. The values of this observer are about 0.5 per cent too low.

⁵⁶ See also p. 382 for O-methyl and ethyl ethers.

⁵⁷ Evidently this value by (78) is too low. Compare the rather good agreement in the case of the methylacetylacetone.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

24. ALIPHATIC KETONES—Continued

[Also those ketones in which the ketone group is not attached to the aromatic nucleus]

$$Q = 26.05 \times N + 6.5$$

Formula	Name	Molec- ular weight	Num- ber of elec- trons (<i>N</i>)	Kg-cal ₁₅ (exper- imental)	Kilo- joules (K. J.)	Kg-cal ₁₅ (calcu- lated to the liquid state)	Literature
C ₇ H ₁₄ O-----	Dipropyl ketone-----	114. 11	40	1, 050. 5	4, 393. 2	1, 048. 5	215; cf. 116.
C ₇ H ₁₄ O-----	Diisopropyl ketone-----	114. 11	40	1, 045. 5	4, 372. 3	1, 048. 5	116.
C ₈ H ₁₆ O-----	Methyl hexyl ketone-----	128. 13	46	1, 205. 1	5, 039. 7	1, 204. 8	215.
C ₆ H ₁₄ O-----	Diallylacetone-----	133. 11	48	1, 280. 7	5, 364. 8	1, 282. 9	171.
C ₁₀ H ₁₆ O-----	Furil (s)-----	190. 05	38	1, 064. 4	4, 454. 5	-----	8.
C ₁₀ H ₁₆ O-----	Acetylphenylacetylene-----	144. 06	46	1, 235. 0	5, 164. 8	1, 231. 4	138.
C ₁₀ H ₁₆ O-----	Furoin (s)-----	192. 06	40	1, 097. 7 1, 114. 0	4, 593. 1 4, 662. 1	-----	241. 8.
C ₁₀ H ₁₆ O-----	Benzalacetone (s)-----	146. 08	48	1, 257. 4	5, 262. 2	1, 266. 4	183.
C ₁₁ H ₁₆ O-----	Propionylphenylacetylene ⁵⁸ -----	158. 08	52	1, 385. 5	5, 794. 2	1, 387. 7	138.
C ₁₁ H ₁₆ O-----	α-Methyl-α-benzalacetone-----	160. 10	54	1, 417. 7	5, 933. 1	1, 419. 7	166.
C ₁₁ H ₁₆ O-----	α-Methyl-α-benzalacetone (s)-----	160. 10	54	1, 413. 5	5, 915. 5	1, 419. 7	166.
C ₁₂ H ₁₈ O-----	Butyrylphenylacetylene-----	172. 10	58	⁵⁸ 1, 537. 9	6, 431. 5	1, 544. 0	138.
C ₁₃ H ₁₈ O-----	Propionylphenylbutine ⁵⁹ -----	186. 11	64	1, 686. 4	7, 052. 5	1, 703. 3	138.
C ₁₃ H ₁₈ O-----	Isovalerylphenylacetylene-----	186. 11	64	^{58, 60} 1, 720. 5	7, 195. 1	1, 700. 3	138.
C ₁₃ H ₁₈ O-----	ψ-Ionone-----	192. 16	70	1, 851. 2	7, 754. 7	1, 868. 5	162.
C ₁₄ H ₁₈ O-----	Caproylphenylacetylene-----	200. 13	70	⁵⁸ 1, 833. 4	7, 667. 3	1, 856. 6	138.
C ₁₇ H ₁₈ O-----	Dibenzalacetone (s)-----	234. 11	80	2, 087. 9	8, 737. 9	2, 103. 5	183.

⁵⁸ The experimental values of the compounds marked show such wide variations for members of an homologous series that undoubtedly it is the fault of the experimenter. The difficulties of obtaining these substances in pure condition may have had something to do with it. Consult original paper.

⁵⁹ C₆H₅.CH₂.CH₂.C≡C-COC₂H₅.

⁶⁰ The author (138) claims that this compound behaves abnormally in many respects.

25. AROMATIC KETONES

$$Q = 26.05 \times N + 6.5 - 3.5a - 6.5b$$

C ₈ H ₈ O-----	Acetophenone (s)-----	120. 06	38	988. 9	4, 138. 6	992. 9	183.
C ₁₃ H ₁₀ O-----	Benzophenone (s)-----	182. 08	60	1, 556. 5	6, 514. 4	1, 562. 5	206; cf. 183, 95.
C ₁₄ H ₁₀ O-----	Benzil (s)-----	210. 08	62	1, 624. 6	6, 798. 9	1, 627. 6	182; cf. 94.
C ₁₄ H ₁₀ O-----	Benzoyl peroxide (s)-----	242. 08	-----	⁶¹ 1, 551. 7	6, 500. 1	-----	163.
C ₁₄ H ₁₂ O-----	Benzoin (s)-----	212. 10	64	1, 671. 4	6, 994. 8	1, 673. 2	182.
C ₁₅ H ₁₀ O-----	Benzoylphenylacetylene (s)-----	206. 08	68	1, 787. 2	7, 474. 1	1, 801. 0	138.
C ₂₁ H ₁₆ O-----	β-Phenylbenzalacetophe- none. ⁶² -----	284. 12	98	2, 545. 3	10, 644. 4	2, 555. 9	95.
C ₂₁ H ₁₆ O-----	β,β-Diphenyl-β-hydroxy- propilphenone-----	302. 15	98	2, 538. 0	10, 613. 9	2, 555. 4	95.

⁶¹ Compare W. A. Roth and R. Lasse, Z. Electrochem., **30**, p. 607; 1924. These authors, using a micro-combustion apparatus, obtained values for this substance which varied within 2 per cent. This discrepancy is due to the fact that the substance does not burn completely and always leaves varying amounts of unburned carbon.

⁶² (C₆H₅)₂:C: $\overset{\text{H}}{\underset{\text{O}}{\text{C}}} - \text{C} - \text{C}_6\text{H}_5$.

26. QUINONES

$$Q = 26.05 \times N + 33.1 - 3.5a - 6.5b$$

C ₆ H ₄ O ₂ -----	Quinone (s) ⁶³ -----	108. 03	24	$\left\{ \begin{array}{l} 656. 3 \\ 656. 6 \end{array} \right.$	$\left\{ \begin{array}{l} 2, 746. 6 \\ 2, 747. 9 \end{array} \right.$	658. 3	225. 180; cf. 30, 43, 222.
C ₇ H ₆ O ₂ -----	Toluquinone (s)-----	122. 05	30	803. 2	3, 361. 4	811. 1	225; cf. 222.
C ₁₀ H ₆ O ₂ -----	α-Napththoquinone (s)-----	158. 05	42	1, 100. 8	4, 606. 9	1, 114. 2	225; cf. 222.
C ₁₀ H ₆ O ₂ -----	β-Napththoquinone (s)-----	158. 05	42	1, 106. 4	4, 630. 3	1, 114. 2	225; cf. 222.
C ₁₀ H ₁₂ O ₂ -----	Thydoquinone (s)-----	164. 10	48	1, 271. 3	5, 320. 4	1, 276. 5	225; cf. 222.
C ₁₄ H ₆ O ₂ -----	Anthraquinone (s)-----	208. 06	60	1, 544. 5	6, 463. 7	1, 562. 0	225; cf. 222.
C ₁₄ H ₆ O ₂ -----	Phenanthraquinone (s)-----	208. 06	60	1, 544. 0	6, 461. 6	1, 562. 5	225; cf. 222.
C ₁₄ H ₈ O ₂ -----	Monohydroxyanthraqui- none (s)-----	224. 06	58	1, 481. 7	6, 200. 9	1, 513. 4	225; cf. 222.

⁶³ The heat of combustion of quinhydrone is given by (180), Z. Phys. Chem., **117**, p. 57, 1925, as 1,334.5 kg-cal₁₅ per mole.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

26. QUINONES—Continued

$$Q = 26.05 \times N + 33.1 - 3.5a - 6.5b$$

Formula	Name	Molecular weight	Number of electrons (<i>N</i>)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₁₄ H ₈ O ₄ -----	1,2-Dihydroxyanthraquinone (s) (Alizarin).	240.06	56	1,448.9	6,063.6	1,464.8	225; cf. 222.
C ₁₄ H ₈ O ₅ -----	1,2,4-Trihydroxyanthraquinone (Purpurin).	256.06	54	1,402.1	5,867.8	1,416.2	225; cf. 222.
C ₁₄ H ₈ O ₈ -----	1,2,3,5,6,7-Hexahydroxyanthraquinone (s) (Rufigallic acid).	304.06	48	1,249.1	5,227.5	1,268.4	225; cf. 222.
C ₁₈ H ₁₀ O ₂ -----	Retenequinone (s) (Methylisopropylphenanthraquinone).	264.13	84	2,152.4	9,007.8	2,187.7	225; cf. 222.

27. HYDROAROMATIC AND POLYMETHYLENE KETONES

$$Q = 26.05 \times N + 6.5$$

C ₅ H ₈ O-----	Acetyltrimethylene.	84.06	26	691.4	2,891.4	-----	215.
C ₅ H ₈ O-----	Cyclopentanone.	84.06	26	682.0	2,852.1	683.8	163.
C ₆ H ₁₀ O-----	β -Methylcyclopentanone.	98.08	32	833.4	3,485.3	840.1	215.
C ₆ H ₁₀ O-----	Acetylcylobutane.	98.08	32	856.8	3,583.1	-----	215.
C ₆ H ₁₀ O-----	3-Methylcyclohexene-2-one-1.	98.08	36	942.9	3,943.2	950.8	149.
C ₇ H ₁₂ O-----	Ethyl-1-cyclopentanone-2.	112.10	38	990.4	4,141.9	996.4	215.
C ₇ H ₁₂ O-----	1,3-Dimethylcyclopentanone-2.	112.10	38	989.8	4,139.3	996.4	215.
C ₇ H ₁₂ O-----	β -Methylcyclohexanone.	112.10	38	994.8	4,160.3	996.4	215.
C ₇ H ₁₂ O-----	Cycloheptanone (Suberone).	112.10	38	996.7	4,168.2	996.4	215.
C ₈ H ₁₂ O-----	1,3-Dimethylcyclohexene-6-one-5.	124.10	42	1,102.2	4,609.4	1,107.1	215.
C ₈ H ₁₄ O-----	1,1-Dimethylcyclohexanone-2.	126.11	44	1,152.1	4,826.2	1,152.7	163.
C ₉ H ₈ O-----	α -Indanone.	132.06	42	1,086.9	4,548.7	1,093.6	236.
C ₉ H ₈ O-----	β -Indanone.	132.06	42	1,088.3	4,554.5	1,093.6	236.
C ₉ H ₁₄ O-----	1,1,5-Trimethylcyclohexene-5-one-3.	138.11	48	1,248.4	5,220.8	1,263.4	215.
C ₉ H ₁₄ O-----	<i>cis</i> - β -Hydrindanone.	138.11	48	1,248.1	5,223.3	1,256.9	83.
C ₉ H ₁₄ O-----	<i>trans</i> - β -Hydrindanone.	138.11	48	1,243.0	5,202.0	1,256.9	83.
C ₉ H ₁₆ O-----	1,4-Methylacetylcylohexane.	140.11	48	1,267.8	5,301.9	1,256.9	215.
C ₉ H ₁₆ O-----	Ethylcyclohexyl ketone.	140.11	50	1,289.5	5,392.7	1,309.0	215.
C ₉ H ₁₆ O-----	Methylcycloheptyl ketone.	140.11	50	1,278.3	5,345.9	1,309.0	215.
C ₁₀ H ₁₄ O-----	Carvone.	150.11	52	1,374.4	5,751.9	1,380.6	201.
C ₁₀ H ₁₄ O-----	Eucarvone.	150.11	52	1,373.1	5,751.9	1,374.1	175.
C ₁₀ H ₁₆ O-----	<i>cis</i> - β -Decalone.	152.13	54	1,404.4	5,877.4	1,413.2	169.
C ₁₀ H ₁₆ O-----	<i>trans</i> - β -Decalone.	152.13	54	1,402.1	5,867.8	1,413.2	169.
C ₁₀ H ₁₆ O-----	Carone.	152.13	-----	1,397.1	5,842.7	-----	50.
C ₁₀ H ₁₆ O-----	Dihydrocarvone.	152.13	54	{ 1,412.2 1,423.7	{ 5,905.8 5,958.2	1,426.2	215. 50; cf. 162.
C ₁₀ H ₁₆ O-----	Carvenone.	152.13	54	{ 1,407.9 1,417.0	{ 5,897.7 5,930.2	1,419.7	162. 50.
C ₁₀ H ₁₆ O-----	Pulegone.	152.13	54	1,412.1	5,915.3	1,426.2	174.
C ₁₀ H ₁₆ O-----	Isopulegone.	152.13	54	1,416.4	5,933.3	1,426.2	162.
C ₁₀ H ₁₆ O-----	Thujone.	152.13	54	1,430.4	5,991.9	-----	175.
C ₁₀ H ₁₆ O-----	Dihydroeucarvone.	152.13	54	{ 1,427.6 1,410.8	{ 5,974.5 5,910.7	1,419.7	50. 125.
C ₁₀ H ₁₆ O-----	Camphor (s).	152.13	54	{ 1,411.0 1,410.8	{ 5,910.7 5,904.2	1,413.2	217; cf. 175, 183, 70.
C ₁₃ H ₂₀ O-----	α -Ionone.	192.16*	70	1,835.4	7,688.5	1,849.5	174.
C ₁₃ H ₂₀ O-----	β -Ionone.	192.16	70	1,839.9	7,707.3	1,849.5	174.

⁶⁴ The correction of 1 per cent applied to (215) values is evidently too large. Roth recommends about 0.6 per cent.

⁶⁵ The author (50) gives values about 0.6 per cent too high.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

28. CARBOHYDRATES (Monosaccharides)

$$Q = 26.05 \times N + 13q + 13j + 6.5k + 3.5l$$

Formula	Name	Molecular weight	Number of electrons (<i>N</i>)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₅ H ₁₀ O ₅ -----	Arabinose (s)-----	150.08	20	{ 558.0 559.9	2,335.2 2,343.2	566.5	195. 87; cf. 31.
C ₅ H ₁₀ O ₅ -----	Xylose (s)-----	150.08	20	{ 561.5 560.5	2,350.3 2,345.7	566.5	185. 87; cf. 31.
C ₆ H ₁₀ O ₅ -----	Levoglucozan (s)-----	162.08	-----	677.7	2,836.2	-----	87.
C ₆ H ₁₂ O ₅ -----	Rhamnose (s)-----	164.10	26	{ 717.9 718.3	3,004.4 3,006.1	722.8	195. 87.
C ₆ H ₁₂ O ₅ .H ₂ O----	Rhamnose (cryst.)-----	182.11	-----	711.5	2,977.6	-----	195.
C ₆ H ₁₂ O ₅ -----	Fucose (s)-----	164.10	26	711.9	2,979.3	722.8	195.
C ₆ H ₁₂ O ₆ -----	<i>d</i> -Glucose (s) (Dextrose)-----	180.10	24	673.0	2,816.5	677.2	182; cf. 195, 64, 87.
C ₆ H ₁₂ O ₆ -----	<i>l</i> -Fructose (s)-----	180.10	24	{ 675.6 671.0	2,827.4 2,805.5	677.2	195. ⁶⁶ 64. ⁶⁶
C ₆ H ₁₂ O ₆ -----	Sorbinose (s) (<i>d</i> -Sorbose)-----	180.10	24	668.3	2,796.8	677.2	195.
C ₆ H ₁₂ O ₆ -----	Galactose (s)-----	180.10	24	{ 669.5 670.7	2,801.9 2,806.9	677.2	195. 87; cf. 48.
C ₇ H ₁₄ O ₇ -----	Glucoheptose (s)-----	210.11	28	783.5	3,276.6	787.9	68.
C ₁₂ H ₂₂ O ₈ -----	Rhamnose triacetate (s) ⁶⁷ -----	290.14	50	1,350.5	5,647.8	1,354.5	87.
C ₁₂ H ₂₂ O ₁₁ -----	Pentaacetylglucose (s)-----	390.17	64	1,726.3	7,219.4	1,725.7	87. ⁶⁶
C ₁₂ H ₂₂ O ₁₁ -----	Pentaacetylgalactose (s)-----	390.17	64	1,725.5	7,216.0	1,725.7	87.

⁶⁶ The heat of combustion of benzoic acid obtained by these investigators is about 0.2 per cent higher than the present international value. Their results are therefore uniformly too high.

⁶⁷ For the method of calculating these compounds, consult the formula for esters.

29. DISACCHARIDES

$$Q = 26.05 \times N + 19.5o + 13j + 6.5k + 3.5l + 13q$$

C ₁₂ H ₂₂ O ₁₁ -----	Cane sugar (s) (Sucrose)-----	342.18	48	1,349.6	5,648.3	-----	230.5; cf. 80, 67, 52, 237, 9, 172, 3, 241, 195, 224, 153, 87.
C ₁₂ H ₂₂ O ₁₁ -----	Milk sugar (anhydr.) (s) (Lactose).	-----	-----	1,350.8	5,653.1	-----	195; cf. 87, 181, ⁶⁸ 74, 88.
C ₁₂ H ₂₂ O ₁₁ .H ₂ O----	Lactose (cryst.) (s)-----	360.19	-----	1,344.7	5,627.6	-----	195; cf. 64, 150, 46.
C ₁₂ H ₂₂ O ₁₁ -----	Maltose (s)-----	342.18	-----	{ 1,350.2 1,351.3	5,649.8 5,655.2	-----	195. 87.
C ₁₂ H ₂₂ O ₁₁ .H ₂ O----	Maltose (cryst.)-----	360.19	-----	1,339.2	5,604.6	-----	195; cf. 64.
C ₁₂ H ₂₂ O ₁₁ -----	Trehalose (s) (Mycose)-----	342.18	-----	1,349.4	5,647.2	-----	183.
C ₁₂ H ₂₂ O ₁₁ .2H ₂ O----	Trehalose (cryst.)-----	378.21	-----	1,341.5	5,614.2	-----	183.
C ₁₂ H ₂₂ O ₁₁ -----	Cellobiose (s) (anhydr.)-----	342.18	-----	1,349.9	5,649.3	-----	87.
C ₂₈ H ₃₈ O ₁₉ -----	Sucrose octaacetate (s)-----	678.3	-----	3,033.3	12,694.4	-----	87.
C ₂₈ H ₃₈ O ₁₉ -----	Maltose octaacetate (s)-----	678.3	-----	3,030.6	12,683.1	-----	87.
C ₂₈ H ₃₈ O ₁₉ -----	Cellobiose octaacetate (s)-----	678.3	-----	3,032.6	12,691.5	-----	87.
C ₂₈ H ₃₈ O ₁₉ -----	Lactose octaacetate (s)-----	678.3	-----	3,029.3	12,677.7	-----	87.

⁶⁸ The author (181) used the potassium chlorate method. The value is unreliable.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

30. TRI, TETRA, AND POLYSACCHARIDES

Formula	Name	Molecular weight	Number of electrons (<i>N</i>)	Kg-cal. ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal. ₁₅ (calculated to the liquid state)	Literature
C ₁₈ H ₃₂ O ₁₆ -----	Raffinose (s) (Melitose)-----	504.26	-----	2,025.5	8,476.7	-----	195; cf. 31.
C ₁₈ H ₃₂ O ₁₆ .5H ₂ O-----	Raffinose (cryst.)-----	504.34	-----	2,018.9	8,449.1	-----	195.
C ₁₈ H ₃₂ O ₁₆ .H ₂ O-----	Melezitose (s)-----	522.23	-----	2,042.0	8,545.8	-----	195.
C ₂₄ H ₄₂ O ₂₁ -----	Stachyose (anhydrous) (s)-----	664.34	-----	2,708.7	11,335.9	-----	87.
	calc.						
	Starch-----			4,178.8	17,488.3	-----	195. ⁶⁹
	Starch acetate-----			4,499.0	18,828.3	-----	87.
	Inulin-----			4,129.9	17,283.6	-----	195.
	Inulin acetate-----			4,190.0	17,535.2	-----	87.
	Dextrin-----			4,522	18,924.6	-----	87.
	Glycogen ⁶⁹ -----			4,107.9	17,191.6	-----	195.
				4,186.8	17,521.8	-----	207; cf. 64,
							75, 133.
	Cellulose-----			4,180.8	17,496.6	-----	195; cf. 76.
	Cellulose acetate-----			4,496.0	18,815.8	-----	87.
	Xylan-----			70 4,243.0	17,756.9	-----	87.
	Xylan acetate-----			4,548.0	19,033.4	-----	87. ⁷¹

⁶⁹ W. K. Slater gives as the heat of combustion of the dry monohydrate C₆H₁₀O₅.H₂O, 3,836×4.182 joules per gram; Biochem. J., 18, p. 629; 1924. The authors (133), on the other hand, report the following values of the mean heats of combustion of glycogen from *Mytilus* and from frog muscle, per gram: Anhydrous glycogen, 4,238; hydrate 4,214; dissolved glycogen, 4,202.

⁷⁰ More probable value, 4,260.0

⁷¹ These authors also give the values for diamylase, α-tetramylase, β-hexamylase, α-octamylase.

31. ALIPHATIC ACIDS⁷²

(Saturated monobasic)

$$Q = 26.05 \times N$$

CH ₂ O ₂ -----	{ Formic acid ⁷³ -----	46.02	2	62.8	262.6	65.1	34, 86.
	{ Formic acid (liq. at 0°)-----			⁷⁴ 62.6	261.8		223.
C ₂ H ₄ O ₂ -----	Acetic acid-----	60.03	8	209.4	875.7	208.4	34.
C ₃ H ₆ O ₂ -----	Propionic acid-----	74.05	14	207.1	866.7		164.
				367.2	1,536.7	364.7	192; cf. 118.
C ₄ H ₈ O ₂ -----	n-Butyric acid-----	88.06	20	524.3	2,194.2	521.0	192; cf. 77.
C ₄ H ₈ O ₂ -----	Isobutyric acid-----	88.06	20	517.4	2,163.8	521.0	117.
C ₅ H ₁₀ O ₂ -----	α-Valeric acid-----	102.08	26	681.6	2,852.5	677.3	192.
				831.0	3,475.2	833.6	215.
C ₆ H ₁₂ O ₂ -----	Caproic acid-----	116.10	32	838.2	3,511.2		66; cf. 115.
C ₆ H ₁₂ O ₂ -----	Isobutylacetic acid-----	116.10	32	837.4	3,504.5	833.6	192.
C ₆ H ₁₂ O ₂ -----	Diethylacetic acid-----	116.10	32	830.8	3,474.4	833.6	227.
C ₇ H ₁₄ O ₂ -----	Ethylpropylacetic acid-----	130.11	38	837.4	3,504.5		192.
C ₇ H ₁₄ O ₂ -----	Heptylic acid-----	130.11	38	994.5	4,161.9	989.9	192.
				986.1	4,123.9	989.9	227.
C ₈ H ₁₆ O ₂ -----	Dipropylacetic acid-----	144.13	44	1,151.6	4,819.4	1,146.2	192.
C ₈ H ₁₆ O ₂ -----	Heptylacetic acid-----	158.14	50	1,309.4	5,479.8	1,302.5	192.
				1,287.4	5,383.9		120.
C ₁₀ H ₂₀ O ₂ -----	Capric acid (s)-----	172.16	56	1,458.1	6,102.1	1,458.8	192.
C ₁₁ H ₂₂ O ₂ -----	Undecylic acid (s)-----	186.18	62	1,615.9	6,762.5	1,615.1	192.
C ₁₂ H ₂₄ O ₂ -----	Lauric acid (s)-----	200.19	68	1,771.7	7,414.6	1,771.4	193.
C ₁₄ H ₂₈ O ₂ -----	Myristic acid (s)-----	228.22	80	2,085.8	8,729.0	2,084.0	193.
C ₁₆ H ₃₂ O ₂ -----	Palmitic acid (s)-----	256.26	92	2,398.4	10,037.3	2,396.6	192. ^{74a}
				2,384.6	9,970.0		64. ^{74b}
C ₁₈ H ₃₆ O ₂ -----	Stearic acid (s)-----	284.29	104	⁷² 2,711.8	11,348.9	2,709.2	192.
				2,697.7	11,279.0		64.
C ₂₀ H ₄₀ O ₂ -----	Arachidic acid (s)-----	312.22	116	3,025.9	12,663.4	3,021.8	192.
C ₂₂ H ₄₄ O ₂ -----	Behenic acid (s)-----	340.35	128	3,338.4	13,971.2	3,334.4	193.

⁷² The values of (192) are uniformly about 0.5 to 0.7 per cent higher than the values for the same compounds recorded by modern investigators.

⁷³ The formula for formic and oxalic acids is $Q = 26.05 \times N + 13$.

⁷⁴ This value is calculated from Thomsen's data. The figure is more or less uncertain, for the specific heat value (4.77 cal.) varies considerably with the temperature.

^{74a} See footnote 72.

^{74b} The values of (64) are uniformly 0.2 per cent high, for the value they employed for benzoic acid was larger than the accepted one by that amount.

⁷⁵ See footnote 72.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

32. ALIPHATIC ACIDS

(Hydroxy and Keto Acids)

$$Q = 26.05 \times N + 6.5s + 13j + 6.5k + 3.5l + 13u + 6.5v + 6.5w$$

Formula	Name	Molecular weight	Number of electrons	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₂ H ₂ O ₃ ·H ₂ O	Dihydroxyacetic acid (s) (Glyoxylic acid).	92.03	4	⁷⁶ 125.5	524.8	130.2	35.
C ₂ H ₄ O ₃	Glycollic acid (s)	76.03	6	166.6	697.2	169.3	182.
C ₃ H ₄ O ₃	Pyroracemic acid	88.03	10	279.1	1,168.0	280.5	49.
C ₃ H ₅ O ₃	Lactic acid (s)	90.05	12	⁷⁷ 326.0	1,363.0	325.6	64; cf. 127, 135, 75, 134. ⁷⁸
C ₄ H ₈ O ₃	Hydroxyisobutyric acid (s)	104.06	18	471.8	1,973.1	481.9	134; cf. 127.
C ₄ H ₈ O ₃	β-Hydroxybutyric acid (s) (Racemic).	104.06	18	487.9	2,039.9	475.4	64.
C ₅ H ₄ O ₃	Pyromucic acid (s)	112.03	-----	489.7	2,049.4	-----	182; cf. 44.
C ₅ H ₈ O ₃	Levulinic acid (s) (β-Acetopropionic acid).	116.06	22	576.8	2,412.2	579.6	18.
C ₂₂ H ₄₄ O ₄	Dihydroxybehenic acid (s)	372.35	124	3,235.7	13,541.4	3,243.2	193.

⁷⁶ See method of calculation for formic and oxalic acids, footnote 73.⁷⁷ This value was obtained by burning a concentrated solution of lactic acid and analyzing the same for carbon and hydrogen.⁷⁸ The value was obtained by burning the ethyl and methyl esters of lactic acid.

33. ALIPHATIC ACIDS (UNSATURATED)

$$Q = 26.05 \times N + 13$$

C ₃ H ₄ O ₂	Acrylic acid	73.02	12	⁷⁹ 327.5	1,369.6	325.6	140; cf. 155.
C ₄ H ₆ O ₂	Crotonic acid (s)	86.05	18	477.7	1,999.2	481.9	183.
C ₅ H ₈ O ₂	Tiglic acid (s)	100.06	24	626.4	2,621.5	631.7	183.
C ₅ H ₈ O ₂	Angellic acid (s)	100.06	24	⁸⁰ 634.8	2,656.6	638.2	183.
C ₅ H ₈ O ₂	α-β-Pentenoic acid (s)	100.06	24	623.7	2,610.2	638.2	166.
C ₅ H ₈ O ₂	β-γ-Pentenoic acid (s)	100.06	24	632.2	2,645.8	638.2	166.
C ₆ H ₈ O ₂	Allylacetic acid	100.06	24	641.6	2,685.1	638.2	167.
C ₆ H ₈ O ₂	Sorbic acid (s)	112.06	28	743.0	3,109.5	755.4	183.
C ₆ H ₁₀ O ₂	Hydrosorbic acid	114.08	30	795.4	3,331.9	794.5	66.
C ₁₀ H ₁₆ O ₂	Geranic acid	168.13	52	1,379.0	5,776.7	1,380.6	171.
C ₁₁ H ₂₀ O ₂	Undecylenic acid (s)	184.16	60	⁸¹ 1,579.7	6,611.0	1,576.0	183.
C ₁₈ H ₃₄ O ₂	Oleic acid	282.27	102	{ 2,657.0 2,681.8	11,108.9 11,223.3	2,663.6	64. 183.
C ₁₈ H ₃₄ O ₂	Elaidic acid (s)	282.27	102	2,664.2	11,149.7	2,670.1	183.
C ₂₂ H ₄₂ O ₂	Brassicic acid (s)	338.34	126	3,290.1	13,769.1	3,288.8	193.
C ₂₂ H ₄₂ O ₂	Erucic acid (s)	338.34	126	3,296.7	13,796.7	3,295.3	193.

⁷⁹ The above is the mean of two determinations which do not agree better than 0.4 per cent.⁸⁰ For method of calculating *cis-trans* isomers, consult formula for maleic acid.⁸¹ Mean value.

34. ALIPHATIC ACIDS (MONOBASIC)

(Acetylene type)

$$Q = 26.05 \times N + 33.1h$$

C ₄ H ₄ O ₂	Tetrollic acid (s)	84.03	16	452.4	1,893.3	449.9	183.
C ₅ H ₁₂ O ₂	Amylpropionic acid	140.09	40	1,083.0	4,529.1	1,075.1	138.
C ₉ H ₁₄ O ₂	Hexylpropionic acid	154.11	46	1,231.8	5,151.4	1,231.4	138.
C ₁₁ H ₁₈ O ₂	Undecolic acid (s)	182.14	58	1,537.8	6,435.7	1,544.0	183.
C ₁₈ H ₃₂ O ₂	Stearolic acid (s)	280.26	100	2,628.6	11,000.7	2,638.1	183.
C ₂₂ H ₄₀ O ₂	Behenolic acid (s)	336.32	124	3,254.9	13,621.8	3,263.3	193.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

35. ALIPHATIC ACIDS (POLYBASIC SATURATED)

$$Q = 26.05 \times N$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₂ H ₂ O ₄ -----	Oxalic acid (s)-----	90.02	2	{ 60.2 60.1	{ 251.9 251.5	⁸² 65.1	190. 235; cf. 86;
C ₃ H ₄ O ₄ -----	Malonic acid (s)-----	104.03	8	{ 207.2 206.5	{ 8,671.3 8,642.0	208.4	190. 235; cf. 127, 121, 123.
C ₄ H ₆ O ₄ -----	Succinic acid (s)-----	118.05	14	{ 356.6 357.1	{ 1,492.4 1,494.5	364.7	190. 235; cf. 123, 127.
C ₄ H ₈ O ₄ -----	Methylmalonic acid (s)-----	118.05	14	{ 362.2 365.0	{ 1,515.8 1,527.5	364.7	192. 190.
C ₅ H ₈ O ₄ -----	Glutaric acid (s)-----	132.06	20	{ 514.7 514.9	{ 2,154.0 2,154.9	521.0	186. 235; cf. 129.
C ₅ H ₈ O ₄ -----	Methylsuccinic acid (s)-----	132.06	20	{ 514.9 515.7	{ 2,154.9 2,158.2	521.0	190. 234; cf. 127.
C ₅ H ₈ O ₄ -----	Ethylmalonic acid (s)-----	132.06	20	517.7	2,166.6	521.0	190.
C ₅ H ₈ O ₄ -----	Dimethylmalonic acid (s)-----	132.06	20	515.1	2,155.7	521.0	190.
C ₆ H ₈ O ₆ -----	Tricarballic acid (s)-----	170.06	20	516.0	2,159.5	521.0	127; cf. 192.
C ₆ H ₁₀ O ₄ -----	Adipic acid (s)-----	146.08	26	{ 668.6 669.0	{ 2,798.1 2,799.8	677.3	190. 235.
C ₆ H ₁₀ O ₄ -----	α-Methylglutaric acid (s)-----	146.08	26	670.6	2,806.5	677.3	190.
C ₆ H ₁₀ O ₄ -----	Ethylsuccinic acid (s)-----	146.08	26	{ 671.9 670.6	{ 2,811.9 2,806.5	677.3	190. 234.
C ₆ H ₁₀ O ₄ -----	Sym. Dimethylsuccinic acid (s) (para-acid).	146.08	26	670.6	2,806.5	677.3	190.
C ₆ H ₁₀ O ₄ -----	Sym. Dimethylsuccinic acid (s) (anti-acid).	146.08	26	674.2	2,821.5	-----	183.
C ₆ H ₁₀ O ₄ -----	Sym. Dimethylsuccinic acid (s) (M. P. 128°) (Racemic).	146.08	26	671.5	2,810.2	677.3	234.
C ₆ H ₁₀ O ₄ -----	Sym. Dimethylsuccinic acid (s) (M. P. 208°) (anti).	146.08	26	673.0	2,816.5	677.3	234.
C ₆ H ₁₀ O ₄ -----	Unsym. Dimethylsuccinic acid (s).	146.08	26	{ 671.4 670.6	{ 2,809.8 2,806.5	677.3	190. 234.
C ₆ H ₁₀ O ₄ -----	Methylethylmalonic acid (s)-----	146.08	26	{ 671.9 ⁸² 675.6	{ 2,811.9 2,827.4	677.3	190. 192.
C ₆ H ₁₀ O ₄ -----	Propylmalonic acid (s)-----	146.08	26	⁸³ 676.1	2,829.5	677.3	192.
C ₆ H ₁₀ O ₄ -----	Isopropylmalonic acid (s)-----	146.08	26	⁸³ 676.1	2,829.5	677.3	192.
C ₇ H ₁₂ O ₄ -----	Pimelic acid (s) (Isopropylsuccinic acid).	160.04	32	{ 822.3 827.5 827.7	{ 3,441.3 3,463.0 3,463.9	833.6	190. 187. 235.
C ₇ H ₁₂ O ₄ -----	Diethylmalonic acid (s)-----	160.10	32	⁸³ 832.6	3,484.4	833.6	192.
C ₇ H ₁₂ O ₄ -----	Trimethylsuccinic acid (s)-----	160.10	32	{ 829.9 985.2 983.3	{ 3,473.1 4,123.0 4,115.1	833.6 989.9	190. 187.
C ₈ H ₁₄ O ₄ -----	Suberic acid (s)-----	174.11	38	{ 983.4 986.7	{ 4,115.5 4,129.3	-----	235; cf. 127.
C ₈ H ₁₄ O ₄ -----	Dimethyladipic acid (s) (sym.).	174.11	38	984.6	4,120.6	989.9	234.
C ₈ H ₁₄ O ₄ -----	Diethylsuccinic acid (s) (unsym.).	174.11	38	986.1	4,126.8	989.9	234.
C ₈ H ₁₄ O ₄ -----	Diethylsuccinic acid (s) (sym.) (M. P. 128°).	174.11	38	987.8	4,133.9	989.9	234.
C ₈ H ₁₄ O ₄ -----	Diethylsuccinic acid (s) (sym.) (M. P. 192°).	174.11	38	988.5	4,136.9	989.9	192.
C ₈ H ₁₄ O ₄ -----	Ethylpropylmalonic acid (s)-----	174.11	38	989.4	4,140.6	989.9	234.
C ₈ H ₁₄ O ₄ -----	Tetramethylsuccinic acid (s)-----	174.11	38	{ 1,141.0 1,141.7	{ 4,775.1 4,778.0	1,146.2	191. 235.
C ₉ H ₁₆ O ₄ -----	Azelaic acid (s)-----	188.13	44	⁸⁵ 1,145.8	4,795.2	1,146.2	192.
C ₉ H ₁₆ O ₄ -----	Dipropylmalonic acid (s)-----	188.13	44	-----	-----	-----	-----

⁸² The calculated heats of combustion for compounds in which 2 weakly electronegative groups, such as COOH, are linked together, is given by the expression $Q = 26.05 \times N + 13$. The correction factor thus denotes that the two carbon atoms share a pair of valence electrons in outer energy levels, compared to a carbon-to-carbon linkage as in ethane.

⁸³ The values of (192) are on the whole about 0.5 to 0.7 per cent too high.

⁸⁴ See footnote 83.

⁸⁵ See footnote 83.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

35. ALIPHATIC ACIDS (POLYBASIC SATURATED)—Continued

$$Q = 26.05 \times N$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal. ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal. ₁₅ (calculated to the liquid state)	Literature
C ₁₀ H ₁₈ O ₄	Sebacic acid (s).....	200.14	50	{ 1,296.4 1,297.3	5,425.4 5,429.2	1,302.5	191. 235; cf. 127.
C ₁₀ H ₁₈ O ₄	Heptylmalonic acid (s).....	200.14	50	⁵⁵ 1,302.4	5,450.5	1,302.5	192.
C ₁₀ H ₁₈ O ₄	Triethylsuccinic acid (s).....	200.14	50	1,301.3	5,445.9	1,302.5	234.
C ₁₁ H ₂₀ O ₄	<i>n</i> -Octylmalonic acid (s).....	216.16	56	⁵⁵ 1,458.1	6,102.1	1,458.8	192.
C ₁₁ H ₂₀ O ₄	Nonanedicarboxylic acid (s).....	216.16	56	1,455.6	6,091.7	1,458.8	235.
C ₁₂ H ₂₂ O ₄	Decanedicarboxylic acid (s).....	230.18	62	1,610.7	6,740.8	1,615.1	235.
C ₁₂ H ₂₂ O ₄	Tetraethylsuccinic acid (s).....	230.18	62	1,618.8	6,774.6	1,615.1	235.
C ₁₃ H ₂₄ O ₄	Brassylic acid (s) (Undecanedicarboxylic acid).....	244.19	68	1,768.6	7,401.6	1,771.4	235.
C ₁₉ H ₃₈ O ₄	Cetylmalonic acid (s).....	328.29	104	⁵⁶ 2,707.3	11,330.0	2,709.2	192.

⁵⁵ See footnote 83.⁵⁶ See footnote 83.

36. HYDROXY POLYBASIC ACIDS (SATURATED)

$$Q = 26.05 \times N + 6.5k + 6.5v$$

C ₃ H ₄ O ₅	Tartronic acid (s).....	120.03	6	165.4	691.7	175.8	130.
C ₃ H ₄ O ₅	Mesoxalic acid (s) (Dihydroxymalonic acid).....	136.03	4	128.2	536.1	136.7	130.
C ₄ H ₆ O ₅	<i>l</i> -Malic acid (s).....	134.05	12	320.1	1,339.6	325.6	75.
C ₄ H ₆ O ₅	<i>d</i> -Tartaric acid (s).....	150.05	10	275.1	1,151.29	286.5	54; cf. 29.
C ₄ H ₆ O ₅	<i>d, l</i> -Tartaric acid (s) (Racemic; anhydr.).....	150.05	10	{ 278.4 273.0	1,164.3 1,142.5	286.5	145, ^{58a} 54.
C ₄ H ₆ O ₅	<i>d, l</i> -Tartaric acid (s) (Racemic; cryst.).....	150.05	10	277.8	1,161.8	286.5	145.
C ₄ H ₆ O ₆	Mesotartaric acid (s) ⁵⁷	150.05	10	276.0	1,155.1	286.5	54.
C ₅ H ₈ O ₇	Trihydroxyglutaric acid (s).....	180.06	14	388.3	1,623.9	397.2	68.
C ₆ H ₁₀ O ₈	Mucic acid (s).....	210.08	18	483.6	2,023.9	-----	183.
C ₆ H ₁₀ O ₈	Allomucic acid (s).....	210.08	18	494.2	2,066.7	507.9	68.
C ₆ H ₈ O ₇	Citric acid (s) (anhydr.).....	192.06	18	474.5	1,985.8	488.4	191; cf. 127.
C ₆ H ₈ O ₇ ·H ₂ O.....	Citric acid (s) (cryst.).....	210.08	18	471.4	1,971.4	-----	127.
C ₈ H ₁₄ O ₈	Dimethyldihydroxyadipic acid (s).....	206.11	34	889.0	3,717.8	898.7	243.

^{58a} Little value should be attached to the work of this investigator. The results are probably not better than 1 to 2 per cent and are too high.

⁵⁷ The authors (54) give also the heat of combustion of various ammonium and substituted ammonium salts of *d*-tartaric, racemic and mesotartaric acids:

	Kg-cal. ₁₅	K. J.		Kg-cal. ₁₅	K. J.
1. Ammonium <i>d</i> -bitartrate.....	341.7	1,430.0	7. Ethylammonium biracemate.....	663.1	2,775.1
2. Ammonium biracemate.....	339.5	1,420.8	8. Phenylammonium <i>d</i> -bitartrate.....	1,079.3	4,516.9
3. Ammonium bimesotartrate.....	341.2	1,427.9	9. Phenylammonium biracemate.....	1,077.3	4,508.5
4. Methylammonium <i>d</i> -bitartrate.....	508.0	2,126.0	10. Benzylammonium biracemate.....	1,229.9	5,147.1
5. Methylammonium biracemate.....	506.0	2,117.6	11. Benzylammonium bimesotartrate.....	1,231.5	5,153.8
6. Ethylammonium <i>d</i> -bitartrate.....	665.4	2,784.7			

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

37. POLYBASIC ALIPHATIC ACIDS (UNSATURATED)

$$Q = 26.05 \times N + 13y + 16.5x$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₄ H ₄ O ₄ -----	Fumaric acid (s) ⁸⁸ (<i>trans</i>)----	116.03	12	320.0	1,339.2	325.6	190; cf. 163, 127, 146.
C ₄ H ₄ O ₄ -----	Maleic acid (s) (<i>cis</i>)-----	116.03	12	326.1	1,364.7	329.1	190; cf. 127, 151.
C ₅ H ₅ O ₄ -----	Itaconic acid (s) (Methyl- enesuccinic acid). }	130.05	18	{ 475.6 475.0	{ 1,990.4 1,987.9	481.9	183. 151; cf. 127.
C ₅ H ₅ O ₄ -----	Citraconic acid (s) (methyl- maleic acid) (<i>cis</i>). }	130.05	18	{ 479.4 478.8	{ 2,006.2 2,003.8	485.4	183. 151; cf. 127.
C ₅ H ₅ O ₄ -----	Mesaconic acid (s) (Methyl- fumaric acid) (<i>trans</i>). }	130.05	18	{ 476.9 475.9	{ 1,995.8 1,991.6	481.9	183. 151; cf. 127.
C ₆ H ₆ O ₆ -----	Aconitic acid (s) }	174.05	18	475.1	1,988.3	481.9	183; cf. 127.
C ₆ H ₆ O ₄ -----	α,β -Hydromuconic acid (s)----	144.06	24	628.8	2,631.5	638.2	183.
C ₆ H ₆ O ₄ -----	β,γ -Hydromuconic acid (s)----	144.06	24	629.1	2,632.8	638.2	183.
C ₆ H ₆ O ₄ -----	Allylmalonic acid (s)----	144.06	24	⁸⁹ 637.8	2,669.2	638.2	192.
C ₇ H ₁₀ O ₄ -----	Tetraconic acid (s) (γ -Di- methylitaconic acid). }	158.08	30	796.1	3,331.7	794.5	145.
C ₄ H ₂ O ₄ -----	Acetylenedicarboxylic acid (s). }	114.02	10	305.9	1,280.2	-----	183.

⁸⁸ A collection of the heats of combustion of some stereoisomeric acids is given by Liebermann, Ber., **35**, p. 90; 1892.

⁸⁹ The values of (192) are from 0.5 to 0.7 per cent too high.

38. AROMATIC ACIDS

$$Q = 26.05 \times N - 3.5a - 6.5b$$

C ₇ H ₅ O ₂ -----	Benzoic acid (s) ⁹⁰ -----	122.05	30	⁹⁰ 771.2	3,227.5	778.0	63; cf. 191, 153, 80, 221, 227, 241, 67, 85, 84, 216, 228, 71, 159, 213, 219, 220, 218, 214.
C ₈ H ₅ O ₂ -----	<i>o</i> -Toluic acid (s)-----	136.08	36	{ 928.9 921.0	{ 3,887.5 3,858.1	930.8	189. 5.
C ₈ H ₅ O ₂ -----	<i>m</i> -Toluic acid (s)-----	136.08	36	{ 928.6 922.2	{ 3,886.2 3,863.1	930.8	189. 5.
C ₈ H ₅ O ₂ -----	<i>p</i> -Toluic acid (s)-----	136.08	36	926.9	3,879.1	930.8	189.
C ₈ H ₅ O ₃ -----	<i>o</i> -Oxymethylbenzoic acid (s)----	152.06	34	887.3	3,713.4	891.7	199.
C ₉ H ₅ O ₃ -----	<i>o</i> -Acetylbenzoic acid (s)----	164.06	38	-----	-----	-----	151.
C ₉ H ₅ O ₃ -----	<i>m</i> -Acetylbenzoic acid (s)----	164.06	38	-----	-----	-----	151.
C ₉ H ₅ O ₃ -----	<i>p</i> -Acetylbenzoic acid (s)----	164.06	38	-----	-----	-----	151.
C ₉ H ₁₀ O ₂ -----	Mesitylenic acid (s)-----	150.08	42	1,084.7	4,539.5	1,083.6	189.
C ₁₀ H ₁₂ O ₂ -----	Cuminic acid (s) (<i>p</i> -Isopropyl- benzoic acid). }	164.10	48	{ 1,238.1 1,231.8	{ 5,181.5 5,155.1	1,243.4	189; cf. 30.
C ₁₁ H ₅ O ₂ -----	α -Naphthoic acid (s)-----	172.06	48	1,227.6	5,137.5	1,233.9	190.
C ₁₁ H ₅ O ₂ -----	β -Naphthoic acid (s)-----	172.06	48	-----	-----	1,233.9	189.

⁹⁰ The above value is the one accepted at the third conference of the International Union of Pure and Applied Chemistry, held at Lyons, 1923. It is the value found by Dickinson, Bull. Bur. Stds., **11**, p. 189; 1915. See also discussion of Verkade in Chem. Weekblad, **19**, p. 339; 1922.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

39. HYDROXY AROMATIC ACIDS

$$Q = 26.05 \times N + 3.5m - 3.5a - 6.5b$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₇ H ₆ O ₃ -----	Salicylic acid (s)-----	138.05	28	⁹¹ 723.1 723.6 726.7 ⁹² 723.8	3, 026.2 3, 028.3 3, 041.2 3, 032.0	729.4	230. 217. 198. 89; cf. 62, 189.
C ₇ H ₆ O ₃ -----	<i>m</i> -Hydroxybenzoic acid (s)---	138.05	28	726.1 724.7	3, 038.7 3, 032.9	729.4	199. 89; cf. 189.
C ₇ H ₆ O ₃ -----	<i>p</i> -Hydroxybenzoic acid (s)---	138.05	28	725.4 723.8	3, 035.8 3, 029.1	729.4	189. 89.
C ₇ H ₆ O ₄ -----	β -Resorecylic acid (s) (2,4-Dihydroxybenzoic acid).	154.05	26	676.5	2, 831.2	680.8	189.
C ₇ H ₆ O ₅ -----	Pyrogallolcarboxylic acid (s)---	170.05	24	633.4	2, 650.8	632.2	189.
C ₇ H ₆ O ₅ -----	Gallic acid (s)-----	170.05	24	633.7	2, 652.0	632.2	189.
C ₈ H ₆ O ₄ -----	Piperonylic acid (s)-----	166.05	30	808.5	3, 362.7	-----	163.
C ₈ H ₆ O ₃ -----	<i>p</i> -Methoxybenzoic acid (s)---	152.06	34	894.6	3, 743.9	901.7	189.
C ₈ H ₆ O ₃ -----	1,6,2-Hydroxytoluic acid (s) ⁹³ .	152.06	34	882.8	3, 694.5	882.2	199.
C ₈ H ₆ O ₃ -----	1,2,3-Hydroxytoluic acid (s)---	152.06	34	878.7	3, 677.4	882.2	199.
C ₈ H ₆ O ₃ -----	1,2,5-Hydroxytoluic acid (s)---	152.06	34	879.5	3, 680.7	882.2	199.
C ₈ H ₆ O ₃ -----	1,2,4-Hydroxytoluic acid (s)---	152.06	34	877.8	3, 673.6	882.2	199.
C ₁₀ H ₁₀ O ₅ -----	Opianic acid (s)-----	210.08	40	1, 089.7	4, 557.1	1, 090.5	106; cf. 107.
C ₁₀ H ₁₀ O ₆ -----	Hemipinic acid (s)-----	226.08	38	1, 025.0	4, 286.6	1, 021.9	107.

⁹¹ As a result of a very exhaustive and painstaking investigation, these authors recommend the use of salicylic acid as a secondary thermochemical standard. Compare Verkade and Coops, *Bull. soc. chim.*, **37**, p. 1536, 1925; Verkade and Coops, *J. Chem. Soc.*, p. 1437, 1926; and particularly Cohen, Verkade, Miyaki, Coops and van der Hoeve, *Verslag Akad. Wetenschappen Amsterdam*, **35**, p. 48; 1926.

⁹² The values of these authors have been corrected to the 15° calorie.

⁹³ The numbers denote the positions of carboxyl, hydroxyl and methyl groups, respectively.

40. PHENYLATED ALIPHATIC ACIDS

$$Q = 26.05 \times N - 3.5a - 6.5b$$

C ₈ H ₈ O ₂ -----	Phenylacetic acid (s)-----	136.06	36	⁹⁴ 930.2	3, 892.9	934.3	208; cf. 66, 241, 5, 106.
C ₈ H ₈ O ₃ -----	Mandelic acid (s)-----	152.06	34	890.3	3, 725.9	895.2	199; cf. 182.
C ₈ H ₈ O ₃ -----	Phenoxyacetic acid (s)-----	152.06	34	902.8	3, 778.2	911.7	199.
C ₉ H ₈ O ₂ -----	Phenylpropionic acid (s)-----	146.05	38	1, 021.1	4, 270.2	1, 016.5	138; cf. 182.
C ₉ H ₈ O ₂ -----	Cinnamic acid (s) (<i>trans</i>)-----	148.06	40	1, 040.2	4, 357.4	1, 048.0	177; cf. 189, 155, ⁹⁵ 145.
C ₉ H ₈ O ₂ -----	Allocinnamic acid (s) (<i>cis</i>) (M. P. 58°).	148.06	40	1, 047.0	4, 385.9	1, 052.0	177; cf. 183, 108.
C ₉ H ₈ O ₂ -----	Atropic acid (s)-----	148.06	40	1, 044.4	4, 370.8	1, 045.0	183; cf. 145.
C ₉ H ₈ O ₃ -----	<i>p</i> -Hydroxycinnamic acid (s) (<i>trans</i>) (M. P. 206°).	164.06	38	991.4	4, 152.9	999.9	177.
C ₉ H ₈ O ₃ -----	Allo- <i>p</i> -hydroxycinnamic acid (s) (<i>cis</i>) (M. P. 126 to 127°).	164.06	38	996.5	4, 174.3	1, 003.4	177.
C ₉ H ₁₀ O ₂ -----	Hydrocinnamic acid (s) (β -phenylpropionic acid).	150.08	42	1, 085.0	4, 540.7	1, 090.6	189.
C ₁₀ H ₈ O ₄ -----	Piperonylacrylic acid (s) (<i>trans</i>) (M. P. 238°).	192.06	40	1, 067.5	4, 471.8	-----	177.
C ₁₀ H ₈ O ₄ -----	Allo-piperonylacrylic acid (s) (<i>cis</i>) (M. P. 99 to 100°).	192.06	40	1, 076.5	4, 509.5	-----	177.
C ₁₀ H ₁₀ O ₂ -----	Phenylisocrotonic acid (s) ⁹⁶ (<i>cis</i>).	162.08	46	1, 195.4	5, 002.8	1, 208.3	183.
C ₁₀ H ₁₀ O ₂ -----	α -Methylcinnamic acid (s)---	162.08	46	1, 198.4	5, 020.1	1, 204.8	163.
C ₁₀ H ₁₀ O ₂ -----	β -Methylcinnamic acid (s)---	162.08	46	1, 197.0	5, 014.2	1, 204.8	163.

⁹⁴ It is most peculiar that these authors obtained 1,042.8 kg-cal₁₅ for this acid while for naphthalene, which was used in standardizing the bomb, their value is 0.9 per cent higher than the accepted value.

⁹⁵ One of these authors showed later (*Ber.*, **35**, p. 2908, 1902), that cinnamic acid upon illumination goes over to a α -truxillic acid. However, upon combustion there was no evidence of any energy difference. See also *Ber.*, **28**, p. 1443; 1895; **46**, p. 267; 1913.

⁹⁶ C₆H₅.CH:CH.CH₂COOH.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

40. PHENYLATED ALIPHATIC ACIDS—Continued

$$Q = 26.05 \times N - 3.5a - 6.5b$$

Formula	Name	Molecular weight	Number of electrons (<i>N</i>)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₁₀ H ₁₀ O ₃ -----	Methylcoumaric acid (s) (<i>trans</i>) (M. P. 182 to 183°).	170.08	44	1,161.0	4,863.4	1,152.5	177.
C ₁₀ H ₁₀ O ₃ -----	Methylcoumarinic acid (s) (<i>cis</i>) (M. P. 91 to 92°).	170.08	44	1,167.2	4,889.4	1,156.0	177.
C ₁₀ H ₁₀ O ₃ -----	<i>p</i> -Methoxycinnamic acid (s) (<i>trans</i>) ⁹⁷	170.08	44	1,163.0	4,871.8	1,172.2	177.
C ₁₀ H ₁₀ O ₃ -----	Allo- <i>p</i> -methoxycinnamic acid (s) (<i>cis</i>) (M. P. 66°).	170.08	44	1,172.2	4,910.4	1,175.7	177.
C ₁₁ H ₁₀ O ₂ -----	Cinnamylidenecetic acid (s) (M. P. 165°).	174.08	50	⁹⁸ 1,310.6	5,480.9	1,322.0	155.
C ₁₁ H ₁₀ O ₂ -----	Allocinnamylidenecetic acid (s) (M. P. 138°).	174.08	50	1,319.4	5,517.7	1,325.5	155.
C ₁₁ H ₁₀ O ₄ -----	Acetylcoumaric acid (s) (<i>trans</i>) (M. P. 154 to 155°).	206.08	46	1,207.6	5,058.6	1,217.8	177.
C ₁₁ H ₁₀ O ₄ -----	Acetylcoumarinic acid (s) (<i>cis</i>) (M. P. 85°).	206.08	46	1,211.7	5,075.8	1,221.3	177.
C ₁₁ H ₁₀ O ₄ -----	Phenylparacetic acid (s)-----	206.08	46	1,195.5	5,003.2	1,204.8	183.
C ₁₁ H ₁₂ O ₃ -----	Ethylcoumaric acid (s) (<i>trans</i>) (M. P. 133 to 134°).	192.10	50	1,316.5	5,514.8	1,328.8	177.
C ₁₁ H ₁₂ O ₃ -----	Ethylcoumarinic acid (s) (<i>cis</i>) (M. P. 101 to 102°).	192.10	50	1,323.0	5,542.0	1,332.0	177.
C ₁₂ H ₁₄ O ₃ -----	Propylcoumaric acid (s) (<i>trans</i>) (M. P. 105 to 106°).	206.11	56	1,470.4	6,159.5	1,484.8	177.
C ₁₂ H ₁₄ O ₃ -----	Propylcoumarinic acid (s) (<i>cis</i>) (M. P. 83 to 84°).	206.11	56	1,476.3	6,184.2	1,488.3	177.
C ₁₂ H ₁₂ O ₃ -----	β -Benzallevulinic acid (s)-----	204.10	54	1,413.4	5,915.1	1,419.7	182.
C ₁₂ H ₁₂ O ₃ -----	δ -Benzallevulinic acid (s)-----	204.10	54	1,410.1	5,901.3	1,419.7	182.
C ₁₃ H ₁₆ O ₃ -----	<i>n</i> -Butylcoumaric acid (s) (<i>trans</i>) (M. P. 89 to 90°).	220.13	62	1,630.6	6,830.6	1,641.1	177.
C ₁₃ H ₁₆ O ₃ -----	<i>n</i> -Butylcoumarinic acid (s) (<i>cis</i>) (M. P. 53 to 54°).	220.13	62	1,637.0	6,857.4	1,644.6	177.
C ₁₄ H ₁₈ O ₃ -----	Isoamylcoumaric acid (s) (<i>trans</i>) (M. P. 79 to 79.5°).	234.14	68	1,789.7	7,497.1	1,797.4	177.
C ₁₄ H ₁₈ O ₃ -----	Isoamylcoumarinic acid (s) (<i>cis</i>) (M. P. 80 to 80.5°).	234.14	68	1,791.3	7,503.8	1,800.9	177.
C ₁₄ H ₁₂ O ₂ -----	Diphenylacetic acid (s)-----	212.10	64	1,651.5	6,911.5	1,654.2	182; cf. 227.
C ₁₄ H ₁₂ O ₃ -----	Benzilic acid (s)-----	228.10	62	1,618.2	6,772.2	1,612.1	182.
C ₁₆ H ₁₆ O ₂ -----	Dibenzylacetic acid (s)-----	240.13	76	1,954.3	8,178.8	1,972.8	227.
C ₁₇ H ₁₆ O ₃ -----	β -Tolylmethoxycinnamic acid (s) (stable).	268.13	78	2,035.2	8,525.5	2,047.9	151.
C ₁₇ H ₁₆ O ₃ -----	β -Tolylmethoxycinnamic acid (s) (labile).	268.13	78	2,039.2	8,542.2	2,047.9	151.

⁹⁷ M. P. 170° (liq. cryst.); clears at 185°.⁹⁸ The work of these investigators is not quite reliable. Thus, the value of standard naphthalene used in the calibration of the bomb is about 0.9 per cent too high, and yet their value for cinnamic acid is within 0.1 per cent of the best value.

41. POLYBASIC AROMATIC ACIDS

$$Q = 26.05 \times N - 3.5a - 6.5b$$

C ₈ H ₆ O ₄ -----	Phthalic acid (s)-----	166.05	30	771.0	3,226.6	774.5	189; cf. 183, 127.
C ₈ H ₆ O ₄ -----	Isophthalic acid (s)-----	166.05	30	768.3	3,215.3	774.5	189.
C ₈ H ₆ O ₄ -----	Terephthalic acid (s)-----	166.05	30	770.4	3,224.1	774.5	189.
C ₈ H ₆ O ₄ -----	Trimelic acid (s)-----	210.05	30	767.0	3,209.9	771.0	189.
C ₈ H ₆ O ₄ -----	Uvic acid (s)-----	185.06	36	928.3	3,884.9	927.3	189.
C ₁₀ H ₆ O ₄ -----	Pyromellitic acid (s) ⁹⁹ -----	254.05	30	776.8	3,250.9	767.5	189.
C ₁₂ H ₈ O ₄ -----	Naphthalic acid (s) (1,8-Naphthalenedicarboxylic acid).	216.05	48	1,244.1	5,202.8	1,230.4	127.
C ₁₂ H ₈ O ₁₂ -----	Mellitic acid (s) ¹ -----	342.05	30	787.5	3,295.7	760.5	189.

⁹⁹ The combustion of these acids was rather unsatisfactory. Consult original paper.¹ See footnote 99.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

42. PHENYLATED POLYBASIC ALIPHATIC ACIDS

$$Q = 26.05 \times N - 3.5a - 6.5b$$

Formula	Name	Molecular weight	Number of electrons (<i>N</i>)	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₁₀ H ₈ O ₄ -----	Benzalmalonic acid (s)-----	192.06	40	1,056.0	4,419.4	1,048.5	183.
C ₁₀ H ₁₀ O ₄ -----	Phenylmalonic acid (s)-----	194.08	42	1,082.5	4,530.3	1,090.6	192.
C ₁₀ H ₁₀ O ₄ -----	Phenylsuccinic acid (s)-----	194.08	42	1,082.3	4,529.4	1,090.6	234.
C ₁₂ H ₁₀ O ₄ -----	Cinnamylidenemalonic acid (s) (yellow).	218.08	50	² 1,319.4	5,517.7	1,322.0	155.
C ₁₆ H ₁₄ O ₄ -----	α -Diphenylsuccinic acid (s) (anhydr.) (easily sol. form). ³	270.11	70	⁴ 1,810.3	7,576.1	1,816.5	182; cf. 145.
C ₁₆ H ₁₄ O ₄ -----	β -Diphenylsuccinic acid (s) (difficultly sol.).	270.11	70	1,806.6	7,560.3	1,816.5	182; cf. 145.
C ₁₅ H ₁₆ O ₄ -----	α -Truxillic acid (s)-----	296.13	80	2,083.5	8,713.2	2,080.0	155.
C ₂₄ H ₂₀ O ₈ -----	Cinnamylidenemalonic acid ⁵ (exposed to the action of light).	436.16	-----	2,638.6	11,034.6	-----	155.

² See footnote 95.³ The heat of combustion of the acetone addition product of α -diphenylsuccinic acid (easily soluble form in acetone) is given as 2,237.9 kg-cal₁₅.⁴ The authors (234) report the heats of combustion of diphenylsuccinic acid (*racem.*) and diphenylsuccinic acid (*anti*) as 1,807.7 kg-cal₁₅ and 1,809.0 kg-cal₁₅, respectively.⁵ The structure suggested for this polymer is C₆H₅.CH.CH.C₆H₅:(CO₂H)₂

43. HYDROAROMATIC AND POLYMETHYLENE ACIDS

$$Q = 26.05 \times N + 13z + 13aa$$

C ₄ H ₈ O ₂ -----	Trimethylenecarboxylic acid (Cyclopropanecarboxylic acid).	86.05	18	{ 479.3 483.7	{ 2,007.8 2,022.8	481.9	175. 215.
C ₅ H ₈ O ₄ -----	α,α -Trimethylenedicarboxylic acid (s) (1,1-Cyclopropanedicarboxylic acid).						
C ₅ H ₈ O ₄ -----	α,β -Trimethylenedicarboxylic acid (s) (<i>cis</i> -1,2-Cyclopropanedicarboxylic acid).	130.05	18	482.9	2,020.9	481.9	187.
C ₅ H ₈ O ₂ -----	Tetramethylenecarboxylic acid (Cyclobutanecarboxylic acid).	100.06	24	{ 641.0 639.2	{ 2,655.2 2,673.1	638.2	175. 215.
C ₆ H ₈ O ₄ -----	α,α -Tetramethylenedicarboxylic acid (s) (1,1-Cyclobutanedicarboxylic acid).						
C ₆ H ₈ O ₄ -----	α,β -Tetramethylenedicarboxylic acid (s) (<i>cis</i> -1,2-Cyclobutanedicarboxylic acid).	144.05	24	642.1	2,687.2	638.2	187.
C ₆ H ₈ O ₄ -----	α,γ -Tetramethylenedicarboxylic acid (s).	144.05	24	639.4	2,673.9	638.2	243.
C ₇ H ₁₂ O ₂ -----	Cyclohexanecarboxylic acid (Hexahydrobenzoic acid) (M. P. 28°).	128.10	36	934.0	3,905.9	937.8	215.
C ₇ H ₁₂ O ₆ -----	Hexahydrotetrahydroxybenzoic acid (s) (Quinic acid).	192.10	28	⁶ 833.3	3,484.9	755.4	43.
C ₇ H ₁₀ O ₂ -----	Δ_2 -Tetrahydrobenzoic acid (s).	126.08	34	885.7	3,710.2	892.2	165.
C ₇ H ₁₀ O ₂ -----	Δ_1 -Tetrahydrobenzoic acid (s).	126.08	34	856.7	3,586.2	892.2	167.
C ₇ H ₁₀ O ₄ -----	α,β -Pentamethylenedicarboxylic acid (s) (<i>trans</i> -1,2-Cyclopentanedicarboxylic acid).	158.08	30	781.5	3,245.9	775.6	187.
C ₇ H ₈ O ₈ -----	$\alpha,\alpha,\beta,\beta$ -Trimethylenetetra-carboxylic acid (s) (1,1,2,2-Cyclopropanetetra-carboxylic acid).	218.05	18	482.7	2,020.1	481.9	187.

⁶ The value for this compound appears to be entirely too large and would certainly bear reinvestigation.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

43. HYDROAROMATIC AND POLYMETHYLENE ACIDS—Continued

$$Q = 26.05 \times N + 13z + 13aa$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₈ H ₈ O ₄ -----	Δ _{1,4} -Dihydroterephthalic acid (s).	168.06	32	835.6	3,497.0	846.6	185.
C ₈ H ₈ O ₄ -----	Δ _{1,5} -Dihydroterephthalic acid (s).	168.06	32	842.1	3,524.2	846.6	185.
C ₈ H ₈ O ₄ -----	Δ _{2,5} -Dihydroterephthalic acid (s) (<i>fum.</i>).	168.06	32	844.9	3,535.9	846.6	186.
C ₈ H ₈ O ₄ -----	Dihydroterephthalic acid (s).	168.06	32	842.6	3,526.3	846.6	186.
C ₈ H ₁₀ O ₄ -----	Δ ₂ -Tetrahydroterephthalic acid (s).	170.08	34	881.1	3,687.4	892.2	186.
C ₈ H ₁₀ O ₄ -----	Δ ₁ -Tetrahydroterephthalic acid (s).	170.08	34	882.3	3,692.4	892.2	185.
C ₈ H ₁₂ O ₂ -----	Cyclohexylideneacetic acid (s). ⁷	140.10	40	1,042.0	4,364.9	1,055.0	167.
C ₈ H ₁₂ O ₂ -----	Cyclohexene-1-acetic acid (s).	140.10	40	1,044.8	4,376.7	1,048.5	167.
C ₈ H ₁₂ O ₄ -----	Hexahydroterephthalic acid (s) (<i>trans</i>).	172.10	36	929.1	3,888.3	937.8	185.
C ₈ H ₁₂ O ₄ -----	Hexahydroterephthalic acid (s) (<i>cis</i>).	172.10	36	928.2	3,884.5	937.8	185.
C ₈ H ₁₂ O ₄ -----	1-2-Cyclohexanedicarboxylic acid (s) (<i>trans</i>).	172.10	36	930.4	3,893.7	937.8	79.
C ₇ H ₄ O ₇ .3H ₂ O-----	Meconic acid (s).	254.08	-----	490.08	2,052.5	-----	106.
C ₈ H ₁₄ O ₂ -----	Cycloheptanecarboxylic acid (s).	142.11	42	1,087.9	4,549.6	1,094.1	215.
C ₈ H ₁₄ O ₂ -----	Hexahydro- <i>m</i> -toluic acid (s) (3-Methylhexamethylene-carboxylic acid).	142.11	42	1,086.2	4,542.5	1,094.1	215.
C ₈ H ₁₄ O ₂ -----	Cyclooctanecarboxylic acid (<i>act</i>).	142.11	42	1,089.2	4,555.0	1,094.1	215.
C ₉ H ₁₄ O ₂ -----	α-Cyclohexene-1-propionic acid.	154.11	46	1,199.6	5,025.1	1,204.8	167.
C ₁₀ H ₁₆ O ₂ -----	Isocampholytic acid (s).	168.13	52	1,363.0	5,700.1	1,367.6	44.
C ₁₀ H ₁₆ O ₂ -----	Campholenic acid (s) (M. P. 50°).	168.13	52	1,365.7	5,711.4	1,367.6	44.
C ₁₀ H ₁₆ O ₃ -----	α-Tanacetoneketocarboxylic acid (s).	184.13	50	1,327.4	5,560.5	1,322.0	175.
C ₁₀ H ₁₆ O ₄ -----	<i>d</i> -Camphoric acid (s).	200.13	48	⁸ 1,243.8	5,205.3	1,250.4	187; cf. 124, 127, 112.
C ₁₀ H ₁₈ O ₂ -----	Campholic acid (s).	170.14	54	1,412.0	5,904.9	1,406.7	44.
C ₁₀ H ₁₈ O ₂ -----	Hexahydrocuminic acid (s).	170.14	54	⁹ 1,396.4	5,839.7	1,406.7	243.
C ₁₂ H ₁₂ O ₁₂ -----	Hexahydromellitic acid (s) (<i>fum</i>).	348.10	36	923.2	3,863.6	937.8	186.

⁷ C₈H₁₀: CH₃COOH.⁸ Values of (124), (127), and (112) vary between 1,242.5 and 1,254.2 kg-cal₁₅.⁹ This value has been corrected according to the method employed by Swietoslawski, J. Amer. Chem. Soc., 42, p. 1093; 1920. The correction factor employed by him appears to be too large, however.

44. ACID ANHYDRIDES

$$Q = 26.05 \times N + 10bb$$

C ₄ H ₂ O ₃ -----	Maleic anhydride (s).	98.02	12	333.9	1,397.4	339.1	182.
C ₄ H ₄ O ₃ -----	Succinic anhydride (s).	100.03	14	369.4	1,545.9	374.3	182.
C ₄ H ₆ O ₃ -----	{ Acetic anhydride (v) Acetic anhydride (liq.)	102.00	16	369.6 458.3 431.9	1,546.8 1,916.6 1,806.2	----- 426.8	234; cf. 127. 223.
C ₅ H ₄ O ₃ -----	Itaconic anhydride (s).	112.03	18	481.5	2,015.1	491.9	183.
C ₅ H ₆ O ₃ -----	Glutaric anhydride (s).	114.05	20	528.0	2,209.7	531.0	183.
C ₅ H ₈ O ₃ -----	Monomethylsuccinic anhydride (s).	114.05	20	527.7	2,208.4	531.0	234.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

44. ACID ANHYDRIDES—Continued

$$Q = 26.05 \times N + 10bb$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₈ H ₈ O ₃ -----	Dimethylsuccinic anhydride (s) (<i>unsym.</i>).	128.06	26	682.6	2,856.7	687.3	234.
C ₈ H ₈ O ₃ -----	Dimethylsuccinic anhydride (<i>sym.</i>) (M. P. 87°).	128.06	26	679.3	2,842.9	687.3	234.
C ₈ H ₈ O ₃ -----	Dimethylsuccinic anhydride (M. P. 43°).	128.06	26	681.1	2,850.4	687.3	234.
C ₈ H ₈ O ₃ -----	Monoethylsuccinic anhydride.	128.06	26	684.8	2,865.9	687.3	234.
C ₆ H ₁₀ O ₃ -----	Propionic anhydride-----	130.08	28	746.6	3,122.3	739.4	118.
C ₇ H ₁₀ O ₃ -----	Trimethylsuccinic anhydride (s).	142.08	32	836.1	3,499.1	843.6	234.
C ₈ H ₄ O ₃ -----	Phthalic anhydride (s)-----	148.03	30	{ 783.4 780.5	{ 3,278.5 3,266.4	784.5	189, 217; cf. 127.
C ₈ H ₁₀ O ₃ -----	Hexahydrophthalic anhydride (s) (sol.) (<i>cis</i>).	154.08	36	932.0	3,900.4	947.8	172.
C ₈ H ₁₂ O ₃ -----	Hexahydrophthalic anhydride (s) (sol.) (<i>trans</i>).	-----	-----	937.8	3,924.7	-----	172.
C ₈ H ₁₂ O ₃ -----	Tetramethylsuccinic anhydride (s).	156.09	38	992.6	4,154.0	999.9	234.
C ₈ H ₁₂ O ₃ -----	Diethylsuccinic anhydride (s) (<i>unsym.</i>).	156.09	38	998.3	4,177.9	999.9	234.
C ₈ H ₁₂ O ₃ -----	Diethylsuccinic anhydride (s) (<i>racem.</i>) (<i>sym.</i>).	156.09	38	995.6	4,166.6	999.9	234.
-----	Diethylsuccinic anhydride (s) (<i>racem.</i>) (<i>anti</i>).	-----	-----	997.2	4,173.2	-----	234.
C ₁₀ H ₈ O ₃ -----	Phenylsuccinic anhydride (s)	176.06	42	1,094.1	4,578.8	2,106.6	234.
C ₁₀ H ₁₄ O ₃ -----	Camphoric anhydride (s)-----	182.11	48	¹⁰ 1,251.8	5,238.8	1,260.4	183; cf. 127, 124.
C ₁₀ H ₁₆ O ₃ -----	Triethylsuccinic anhydride (s).	184.12	50	1,309.5	5,480.3	1,312.5	234.
C ₁₂ H ₈ O ₃ -----	Naphthalic anhydride (s)-----	198.05	48	¹¹ 1,257.6	5,259.3	1,240.4	127.
C ₁₂ H ₂₀ O ₃ -----	Tetraethylsuccinic anhydride (s).	212.15	62	1,621.3	6,785.1	1,625.1	234.
C ₁₂ H ₂₂ O ₃ -----	Diethylacetic anhydride (s)---	214.18	64	1,669.1	6,980.2	1,677.2	227.
C ₁₄ H ₁₆ O ₃ -----	Benzoic anhydride (s)-----	226.08	60	1,555.1	6,508.1	1,566.0	205; cf. 227.
C ₁₄ H ₂₆ O ₃ -----	Heptylic anhydride (s)-----	242.21	76	1,985.5	8,303.4	1,989.8	227.
C ₁₆ H ₁₂ O ₃ -----	Diphenylsuccinic anhydride (<i>racem.</i>) (s).	252.10	70	1,815.9	7,599.5	1,826.5	234.
C ₁₆ H ₁₀ O ₃ -----	Diphenylmaleic anhydride (s).	250.08	68	1,768.9	7,402.9	1,774.9	182.
C ₁₈ H ₁₄ O ₃ -----	Cinnamic anhydride (s)-----	298.11	80	2,091.3	8,745.8	2,107.0	227.
C ₂₈ H ₂₂ O ₃ -----	Diphenylacetic anhydride (s).	406.18	128	3,308.0	13,834.1	3,337.4	227.
C ₃₂ H ₃₀ O ₃ -----	Dibenzylacetic anhydride (s) (glassy).	462.24	152	3,931.4	16,441.1	3,962.6	227.

¹⁰ The mean of several values.¹¹ Individual determinations do not agree better than 0.7 per cent; values of (127) are also on the whole 1 per cent higher than those of (183).

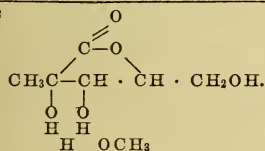
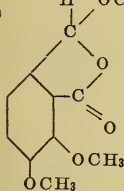
VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

45. LACTONES

$$Q = 26.05 \times N + 13$$

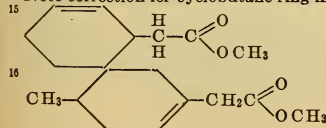
Formula	Name	Molecular weight	Number of electrons (<i>N</i>)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₈ H ₁₀ O ₅	Saccharinic acid lactone (s) ¹²	162.08	24	656.6	2,747.9	662.2	195.
C ₈ H ₁₀ O ₅	<i>l</i> -Gulonolactone (s).....	178.08	22	614.7	2,570.7	625.1	68.
C ₈ H ₁₀ O ₅	<i>l</i> -Mannolactone (s).....	178.08	22	616.3	2,577.4	625.1	68.
C ₈ H ₁₀ O ₅	<i>d</i> -Mannolactone (s).....	178.08	22	618.7	2,587.4	625.1	68.
C ₇ H ₁₀ O ₄	Terebic acid (s) (γ,γ-Dimethylparaconic acid).	158.08	30	778.3	3,254.9	794.5	145.
C ₇ H ₁₂ O ₇	Glucuheptonic acid lactone (s).	208.10	26	726.3	3,037.4	735.8	68.
C ₈ H ₆ O ₂	Phthalide (s).....	134.05	34	884.1	3,699.9	891.7	199; cf. 157.
C ₈ H ₁₄ O ₅	Glucuoctonolactone (s).....	238.11	30	836.7	3,499.1	843.5	68.
C ₁₀ H ₁₀ O ₄	Meconine (Dimethoxyphthalide).	194.08	42	1,136.7	4,753.7	1,139.1	106; cf. 107.
C ₁₁ H ₁₂ O ₅	Methyl opianate (s).....	224.10	46	¹³ 1,262.9	5,281.5	1,139.1	106.

¹²¹³

46. METHYL ESTERS OF MONOBASIC ACIDS

$$Q = 26.05 \times N + 16.5$$

C ₂ H ₄ O ₂	Methyl formate (v).....	60	8	240.2	1,004.5	-----	223; cf. 40.
	Methyl formate (liq.).....	60.03		233.1	974.8	-----	26.
C ₃ H ₆ O ₂	Methyl acetate (v).....	74	14	397.7	1,663.2	-----	223.
	Methyl acetate (liq.).....	74.05		390.0	1,631.0	381.2	78.
C ₄ H ₈ O ₂	Methyl propionate (v).....	88	20	552.3	2,309.7	537.5	223.
C ₄ H ₈ O ₂	Methyl lactate.....	104.06	18	497.2	2,079.3	498.3	75.
C ₅ H ₁₀ O ₂	Methyl butyrate.....	102	26	692.8	2,897.3	693.8	65.
C ₅ H ₁₀ O ₂	Methyl isobutyrate.....	102.08	26	694.2	2,904.5	693.8	154.
C ₅ H ₁₀ O ₂	Methyl acetylacetate.....	116.06		594.0	2,484.1	-----	78.
C ₆ H ₁₀ O ₂	Methyl dimethylacrylate.....	114.08	30	804.4	3,369.6	810.8	163.
C ₆ H ₁₀ O ₂	Methyl cyclobutanecarboxylate.	114.08	30	¹⁴ 809.1	3,383.7	810.8	215.
C ₉ H ₁₄ O ₂	Methyl cyclohexene-1-acetate. ¹⁵	154.11	46	1,210.1	5,069.1	1,221.3	167.
C ₉ H ₁₄ O ₂	Methyl cyclohexylideneacetate.	154.11	46	1,216.5	5,095.9	1,221.3	167.
C ₁₀ H ₁₆ O ₂	Methyl α-cyclohexene-1-propionate.	168.13	52	1,349.3	5,652.2	-----	167.5.
C ₁₀ H ₁₆ O ₂	Methyl methyl-4-cyclohexylidene-1-acetate. ¹⁶	168.13	52	1,373.9	5,755.3	1,377.6	167.
C ₁₀ H ₁₆ O ₂	Methyl methyl-4-cyclohexene-1-acetate.	168.13	52	1,362.0	5,705.5	1,377.6	167.
C ₁₀ H ₁₆ O ₂	Methyl α-cyclohexylidene-propionate.	168.13	52	1,374.6	5,758.2	1,377.6	167.
C ₁₁ H ₁₈ O ₃	Methyl pinonate.....	198.14	56	1,477.3	6,188.4	1,481.8	175.

¹⁴ Note correction for cyclobutane ring in formula for polymethylenecarboxylic acids.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

47. METHYL ESTERS OF MONOBASIC AROMATIC ACIDS

$$Q = 26.05 \times N + 16.5 - 3.5a - 6.5b$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₈ H ₈ O ₂ -----	Methyl benzoate-----	136.06	36	943.5	3,948.6	950.8	205.
C ₈ H ₈ O ₃ -----	Methyl salicylate-----	152.06	34	898.3	3,759.4	902.2	206.
C ₈ H ₈ O ₃ -----	Methyl <i>p</i> -hydroxybenzoate (s).-----	152.06	34	895.4	3,747.3	902.2	191.
C ₉ H ₈ O ₃ -----	Methyl gallate (s)-----	184.06	30	801.6	3,354.7	805.0	191.
C ₉ H ₁₀ O ₃ -----	Methyl anisate (s)-----	166.08	40	1,068.7	4,472.5	1,074.5	191.
C ₁₀ H ₁₀ O ₂ -----	Methyl cinnamate (s)-----	162.08	46	{ 1,213.0 1,210.4	5,076.4 5,070.4	1,221.3	191. 163.
C ₁₀ H ₈ O ₂ -----	Methyl phenylpropionate-----	160.06	44	1,196.2	5,002.5	1,189.3	138.
C ₁₂ H ₁₀ O ₂ -----	Methyl <i>β</i> -naphthoate (s)-----	186.08	54	1,401.5	5,865.3	1,406.7	191.
C ₁₂ H ₁₄ O ₃ -----	Methyl ethylcoumarate (trans).-----	206.11	56	1,490.3	6,242.9	1,501.3	177.
C ₁₂ H ₁₄ O ₃ -----	Methyl ethylcoumarinate (cis).-----	206.11	56	1,495.0	6,262.6	1,504.8	177.

48. METHYL ESTERS OF POLYBASIC ALIPHATIC ACIDS

$$Q = 26.05 \times N + 16.5dd$$

C ₅ H ₈ O ₃ -----	Dimethyl carbonate-----	90.05	12	{ 340.8 401.9	7,290.5 1,681.9	345.7 410.8	215; cf. 119. 191.
C ₄ H ₆ O ₄ -----	Dimethyl oxalate (s)-----	118.05	14	{ 401.0 552.2	1,678.2 2,309.3	----- 554.1	233. 78.
C ₅ H ₈ O ₄ -----	Dimethyl malonate-----	132.06	20	{ 554.3 -----	2,319.8 -----	----- -----	233. -----
C ₆ H ₈ O ₄ -----	Dimethyl fumarate (s)-----	144.06	24	664.3	2,780.1	¹⁷ 671.3	191; cf. 145.
C ₆ H ₈ O ₄ -----	Dimethyl maleate (s)-----	144.06	24	669.2	2,798.6	674.8	145.
C ₆ H ₁₀ O ₄ -----	{ Dimethyl succinate----- Dimethyl succinate (s)-----	146.06	26	{ 708.2 707.4 703.3	2,963.8 2,960.5 2,943.3	710.4	191. 233. 191.
C ₆ H ₁₀ O ₆ -----	Dimethyl racemate (s)-----	178.08	22	{ ^{17a} 617.8 617.3	2,583.6 2,581.6	-----	145. 10; cf. 180.
C ₆ H ₁₀ O ₆ -----	<i>d</i> -Dimethyl tartrate (s)-----	178.08	22	{ 619.0 618.3	2,588.7 2,585.8	-----	145. 10 cf; 9.
C ₆ H ₁₀ O ₆ -----	Dimethyl mesotartrate (s)-----	178.08	22	617.3	2,581.6	632.2	10; cf. 180.
C ₇ H ₁₀ O ₄ -----	Dimethyl trimethylene- <i>α</i> , <i>α</i> -dicarboxylate-----	158.08	30	826.9	3,463.9	827.6	175.
C ₇ H ₁₀ O ₅ -----	Dimethyl acetylmalonate-----	174.08	28	752.8	3,148.2	769.0	78.
C ₇ H ₁₂ O ₄ -----	Dimethyl glutarate-----	160.09	32	863.2	3,612.5	866.7	233.
C ₈ H ₁₂ O ₄ -----	Dimethyl tetramethylene- <i>α</i> , <i>β</i> -dicarboxylate-----	172.10	36	983.5	4,119.9	983.8	175.
C ₈ H ₁₄ O ₄ -----	Dimethyl adipate-----	174.11	38	1,019.6	4,267.0	1,023.0	233.
C ₉ H ₁₆ O ₄ -----	Dimethyl pimelate-----	188.12	44	1,176.0	4,921.5	1,179.3	233.
C ₁₀ H ₁₈ O ₄ -----	Dimethyl suberate-----	202.14	50	1,333.2	5,579.4	1,335.6	233.
C ₁₁ H ₂₀ O ₄ -----	Dimethyl azelate-----	216.15	56	1,488.3	6,228.5	1,491.9	233.
C ₁₂ H ₂₂ O ₄ -----	{ Dimethyl sebacate----- Dimethyl sebacate (s)-----	230.17	62	{ 1,644.7 1,635.8	6,883.1 6,845.8	1,648.2	233. 233.
C ₉ H ₁₄ O ₇ -----	Trimethyl citrate (s)-----	234.11	36	983.0	4,113.9	993.9	191.
C ₉ H ₁₄ O ₄ -----	Dimethyl pentamethylene- <i>αβ</i> -dicarboxylate-----	186.11	42	1,116.6	4,677.4	1,127.2	175.
C ₁₀ H ₁₂ O ₄ -----	Dimethyl <i>Δ</i> -1,4-dihydroterephthalate (s).-----	196.1	44	1,180.6	4,940.8	1,192.3	185.
C ₁₀ H ₁₄ O ₄ -----	Dimethyl <i>Δ</i> -tetrahydroterephthalate (s).-----	198.11	46	1,226.2	5,131.7	1,237.8	185.

¹⁷ The heat of fusion of dimethyl fumarate is 8.3, which would bring the calculated value to approximately 663.0 kg-cal.

^{17a} The work of (10) is much more accurate than that of (145), and preference should be given to his values. The values of (145) are included here merely to allow one to estimate the accuracy of his results and to use this information as a guide in estimating the accuracy of his measurements when no other measurements are available. His results vary widely. On the whole, they are not to be trusted to an accuracy greater than 0.5 per cent, and in many cases the values are not better than 1 to 2 per cent.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

48. METHYL ESTERS OF POLYBASIC ALIPHATIC ACIDS—Continued

$$Q = 26.05 \times N + 16.5dd$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₁₀ H ₁₄ O ₈ -----	Tetramethyl ethanetetra-carboxylate (s) (<i>sym.</i>).	262.11	38	1,045.1	4,373.7	1,056.0	183.
C ₁₀ H ₁₆ O ₄ -----	Dimethyl norpinate (<i>cis</i>) (Dimethyl 1,1-dimethyl-cyclobutane-2,4-dicarboxylate).	200.13	48	1,287.5	5,393.3	1,296.5	175.
C ₁₀ H ₁₈ O ₄ -----	Dimethyl hexahydroterephthalate (<i>fum</i>) (s)	200.13	48	1,273.5	5,329.6	1,283.5	185.
C ₁₁ H ₁₄ O ₈ -----	Tetramethyl α , α , β , β -trimethylenetetra-carboxylate (s).	274.11	42	1,169.7	4,895.2	1,173.2	187.
C ₁₁ H ₁₆ O ₄ -----	Dimethyl spiroheptanedicarboxylate.	212.13	52	1,407.7	5,896.9	1,400.6	175.
C ₁₁ H ₁₈ O ₈ -----	Tetramethyl methylenedimalonate ¹⁸ (s).	276.13	44	1,201.4	5,027.9	1,212.3	187.
C ₁₁ H ₁₈ O ₄ -----	Dimethyl α -tanacetonedicarboxylate.	214.14	54	1,451.4	6,079.9	1,452.7	175.
C ₁₁ H ₁₈ O ₄ -----	Dimethyl pinate.	214.14	54	1,440.2	6,032.9	1,452.7	175.

¹⁸ (CH₃.CO₂)₂.CH.CH₂.CH(CO₂CH₃)₂.

49. METHYL ESTERS OF POLYBASIC AROMATIC ACIDS

$$Q = 26.05 \times N + 16.5dd - 3.5a - 6.5b$$

C ₁₀ H ₁₀ O ₄ -----	Dimethyl phthalate.	194.08	42	1,119.7	4,685.9	1,120.1	191.
C ₁₀ H ₁₀ O ₄ -----	Dimethyl isophthalate (s)	194.08	42	1,111.1	4,649.9	1,120.1	191.
C ₁₀ H ₁₀ O ₄ -----	Dimethyl terephthalate (s)	194.08	42	1,111.6	4,652.0	1,120.1	191; cf. 185.
C ₁₂ H ₁₂ O ₆ -----	Trimethyl trimesate (s)	252.10	48	1,291.7	5,405.8	1,289.4	191.
C ₁₈ H ₁₈ O ₄ -----	Dimethyl diphenylmaleate (s).	296.13	80	2,111.9	8,838.3	2,120.5	183.
C ₁₈ H ₁₈ O ₁₂ -----	Hexamethyl mellitate (s)	426.13	66	1,824.3	7,634.7	-----	191.
C ₂₀ H ₂₀ O ₄ -----	Dimethyl β -truxillate (s)	324.16	-----	2,421.6	10,134.4	-----	183.

¹⁹ This value is not quite satisfactory, although it is the mean of a number of determinations.

50. ETHYL ESTERS OF MONOBASIC ALIPHATIC ACIDS

$$Q = 26.05 \times N + 16.5$$

C ₃ H ₆ O ₂ -----	Ethyl formate (v)-----	74.0	14	398.4	1,666.1	-----	223.
	Ethyl formate (liq)-----	74.05	-----	391.7	1,638.1	-----	26; cf. 65.
C ₄ H ₈ O ₂ -----	Ethyl acetate (v)-----	88.0	20	544.4	2,276.7	537.5	223.
	Ethyl acetate (liq)-----	88.06	-----	536.9	2,245.3	-----	78.
				539.9	2,257.9	-----	172.
C ₅ H ₈ O ₂ -----	Ethyl propionate.	98.05	22	634.8	2,654.7	635.7	138.
C ₅ H ₁₀ O ₂ -----	Ethyl propionate.	102.08	26	690.8	2,891.0	693.8	172.
C ₅ H ₁₀ O ₃ -----	Ethyl lactate.	118.08	24	653.3	2,732.1	654.7	75; cf. 118.
C ₆ H ₁₀ O ₃ -----	Ethyl acetoacetate.	130.08	28	753.6	3,151.6	755.4	112.
C ₆ H ₁₂ O ₂ -----	Ethyl n-butyrate.	116.10	32	851.2	3,559.7	850.1	118.
C ₆ H ₁₂ O ₂ -----	Ethyl isobutyrate.	116.10	32	845.7	3,536.7	850.1	118.
C ₇ H ₁₂ O ₂ -----	Ethyl tetramethylenecarboxylate.	128.10	36	965.1	8,297.9	967.3	175.
C ₇ H ₁₂ O ₂ -----	Ethyl angelate.	128.10	36	964.2	4,035.2	967.8	151.
C ₇ H ₁₂ O ₂ -----	Ethyl tiglate (s)	128.10	36	954.4	3,994.2	967.8	151.
C ₇ H ₁₂ O ₂ -----	Ethyl allylacetate.	128.10	36	971.5	4,065.7	967.8	151.
C ₇ H ₁₂ O ₃ -----	Ethyl α -ethoxyacrylate (s)	144.10	34	926.1	3,875.7	934.7	166.
C ₇ H ₁₂ O ₃ -----	Ethyl β -ethoxyacrylate.	144.10	34	923.4	3,864.4	934.7	166.
C ₇ H ₁₄ O ₂ -----	Ethyl valerate.	130.11	38	1,017.5	4,255.1	1,006.4	65.
C ₈ H ₁₂ O ₂ -----	Ethyl sorbate.	140.10	40	1,012.0	4,239.3	-----	162.
C ₈ H ₁₂ O ₄ -----	Ethyl diacetylacetate.	172.10	36	972.1	4,065.3	967.3	78.

²⁰ This value is apparently too low and would bear reinvestigation.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

50. ETHYL ESTERS OF MONOBASIC ALIPHATIC ACIDS—Continued

$$Q = 26.05 \times N + 16.5$$

Formula	Name	Molec- ular weight	Num- ber of elec- trons (<i>N</i>)	Kg-cal ₁₅ (experi- mental)	Kilo- joules (K. J.)	Kg-cal ₁₅ (calcu- lated to the liquid state)	Literature
C ₈ H ₁₄ O ₃ -----	Ethyl α-ethoxycrotonate (s)	158.11	40	1,076.9	4,506.8	1,091.0	166.
C ₈ H ₁₄ O ₃ -----	Ethyl α-ethylacetoacetate...	158.11	40	1,070.9	4,481.6	1,068.0	242.
C ₁₀ H ₁₆ O ₂ -----	Ethyl β, δ-dimethylsorbate...	168.13	52	1,351.3	6,078.8	-----	162.
C ₁₀ H ₁₈ O ₂ -----	Ethyl amylpropionate.....	168.13	52	1,394.0	5,829.7	1,404.2	138.
C ₁₀ H ₁₆ O ₂ -----	Ethyl (cyclohexene-1)-ac- etate.	168.13	52	1,360.4	5,698.7	1,377.6	167.
C ₁₀ H ₁₆ O ₂ -----	Ethyl cyclohexylidene acetate.	168.13	52	1,367.0	5,726.4	1,384.1	167.
C ₁₁ H ₁₆ O ₂ -----	Ethyl 1-methylcyclohexene- 1-methene-3-carboxylate.	180.13	-----	1,477.0	6,187.2	-----	174.
C ₁₁ H ₁₈ O ₂ -----	Ethyl hexylpropionate.....	182.14	58	1,550.8	6,485.5	1,560.5	138.
C ₁₁ H ₁₈ O ₂ -----	Ethyl α-(cyclohexene-1)- propionate.	182.14	58	1,501.5	6,289.8	-----	167.
C ₁₁ H ₁₈ O ₃ -----	Ethyl methyl-1-ethyl-4-cy- clopentanone carboxylate. ²³	198.14	-----	1,465.8	6,129.9	-----	215.
C ₁₂ H ₁₈ O ₂ -----	Ethyl 1,3-Dimethyl-4-cy- clohexene-3-methene-5- carboxylate.	194.14	-----	1,631.4	6,833.9	-----	176.

²¹ This value appears to be low.²² This value appears to be low.

²³ In the article by Swietoslawski (*J. Amer. Chem. Soc.*, 40, p. 1099; 1920) the compound is named "ethyl ester of methylethyl-1,4-cyclopentanecarboxylic acid." However, neither the empirical formula nor the molecular weight corresponds to the above name. The above formula is suggested, for it corresponds to the molecular weight given.

51. ETHYL ESTERS OF MONOBASIC AROMATIC ACIDS

$$Q = 26.05 \times N + 16.5 - 3.5a - 6.5b$$

C ₉ H ₁₀ O ₂ -----	Ethyl benzoate.....	150.08	42	1,098.7	4,598.1	1,107.1	205.
C ₉ H ₁₀ O ₃ -----	Ethyl salicylate.....	166.08	40	1,051.2	4,399.3	1,055.0	206.
C ₉ H ₁₀ O ₃ -----	Ethyl <i>p</i> -hydroxybenzoate (s)	166.08	40	1,042.8	4,364.1	1,055.0	206.
C ₁₁ H ₁₀ O ₂ -----	Ethyl phenylpropionate.....	174.08	50	1,338.6	5,598.0	1,345.6	138.
C ₁₂ H ₁₄ O ₂ -----	Ethyl α-methylcinnamate ²⁴	190.11	58	1,526.8	6,395.8	1,533.9	163.
C ₁₂ H ₁₄ O ₂ -----	Ethyl β-methylcinnamate...	190.11	58	1,527.5	6,398.7	1,533.9	163.
C ₁₂ H ₁₄ O ₃ -----	Ethyl methylcoumarinate...	206.11	56	1,494.2	6,259.2	1,501.3	177.

²⁴ See also Ber., 25, p. 90; 1892, for heats of combustion of polymers of ethyl cinnamate.

52. ETHYL ESTERS OF POLYBASIC ALIPHATIC ACIDS

$$Q = 26.05 \times N + 16.5dd$$

C ₅ H ₁₀ O ₃ -----	Diethyl carbonate.....	118.08	24	647.9	2,709.5	-----	215.
C ₆ H ₁₀ O ₄ -----	Diethyl oxalate.....	146.08	26	642.1	2,685.3	-----	119.
C ₇ H ₁₂ O ₄ -----	Diethyl malonate.....	160.10	32	716.0	2,994.3	723.3	119.
				860.4	3,598.2	866.6	119.
C ₈ H ₁₄ O ₄ -----	Diethyl succinate.....	174.11	38	1,007.3	4,212.5	1,022.9	119.
C ₈ H ₁₄ O ₆ -----	Diethyl d-tartrate.....	206.11	34	930.6	3,894.6	931.7	9.
C ₈ H ₁₄ O ₆ -----	Diethyl mesotartrate.....	206.11	34	931.3	3,896.9	931.7	9.
C ₈ H ₁₀ O ₄ -----	Diethyl acetylenedicarboxy- late.	170.08	34	957.6	4,004.7	951.8	138.
C ₁₀ H ₁₈ O ₄ -----	Diethyl dimethylsuccinate (<i>sym.</i>).	202.14	50	1,328.9	5,561.4	1,335.5	183.
C ₁₀ H ₁₈ O ₄ -----	Diethyl dimethylsuccinate (<i>rac.</i>).	202.14	50	1,322.9	5,536.3	1,335.5	9.
C ₁₀ H ₁₈ O ₄ -----	Diethyl dimethylsuccinate (<i>meso</i>) (s).	202.14	50	1,324.1	5,541.4	1,335.5	9.
C ₁₂ H ₂₀ O ₇ -----	Triethyl citrate.....	276.16	54	1,459.1	6,101.9	1,462.7	118.
C ₁₄ H ₂₀ O ₈ -----	Tetraethyl ethylenetetra-car- boxylate (s).	316.16	60	1,627.7	6,811.9	1,642.0	183.
C ₁₄ H ₂₂ O ₈ -----	Tetraethyl ethanetetra-car- boxylate (<i>sym.</i>) (s).	318.18	62	1,661.2	6,952.1	1,681.1	-----
C ₂₀ H ₂₂ O ₄ -----	Diethyl diphenylsuccinate (<i>rac.</i>) (s).	326.18	94	2,450.8	10,256.6	2,474.9	166.
C ₂₀ H ₂₂ O ₄ -----	Diethyl diphenylsuccinate (<i>meso</i>) (s).	326.18	94	2,449.4	10,250.7	2,474.9	166.

VIII. TABLES OF DATA—Continued

2. CHO COMPOUNDS—Continued

53. ESTERS OF ALIPHATIC ACIDS

(All types)

$$Q = 26.05 \times N + 16.5dd$$

Formula	Name	Molecular weight	Number of electrons (<i>N</i>)	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₄ H ₈ O ₂ -----	Allyl formate (v)-----	86. 0	18	525. 8	2, 198. 9	-----	223.
C ₄ H ₈ O ₂ -----	Vinyl acetate-----	86. 05	18	498. 1	2, 084. 5	498. 4	164.
C ₅ H ₈ O ₂ -----	Allyl acetate-----	100. 06	24	655. 8	2, 742. 6	654. 7	119.
C ₇ H ₁₄ O ₂ -----	Amyl acetate-----	130. 11	40	²⁵ 1, 042. 5	4, 359. 7	1, 058. 5	158.
C ₁₂ H ₂₀ O ₂ -----	Propyl hexylpropionate-----	196. 16	64	1, 717. 3	7, 181. 8	1, 716. 8	138.
C ₁₈ H ₃₆ O ₂ -----	Cetyl acetate (s)-----	284. 2	104	2, 728. 1	11, 417. 1	2, 725. 7	183.
C ₃₂ H ₆₄ O ₂ -----	Cetyl palmitate (s)-----	480. 51	188	4, 872. 8	20, 392. 7	4, 913. 9	181.

²⁵ The accuracy of the method employed and the value for the compound given are probably not better than 1 per cent.

54. ESTERS OF AROMATIC ACIDS

(All types)

$$Q = 26.05 \times N + 16.5$$

C ₁₀ H ₁₂ O ₂ -----	Propyl benzoate-----	164. 10	48	1, 254. 5	5, 250. 1	1, 263. 4	205.
C ₁₀ H ₁₂ O ₂ -----	Propyl salicylate-----	180. 10	46	1, 205. 7	5, 045. 9	1, 214. 8	206.
C ₁₀ H ₁₂ O ₃ -----	Propyl <i>p</i> -hydroxybenzoate (s)-----	180. 10	46	1, 200. 6	5, 024. 5	1, 214. 8	206.
C ₁₁ H ₁₄ O ₂ -----	Isobutyl benzoate-----	178. 11	54	1, 411. 4	5, 906. 7	1, 419. 7	205.
C ₁₁ H ₁₄ O ₃ -----	Isobutyl salicylate-----	194. 0	52	1, 365. 5	5, 714. 6	1, 371. 1	206.
C ₁₂ H ₁₆ O ₂ -----	Amyl benzoate-----	192. 13	60	1, 569. 5	6, 568. 4	1, 576. 0	205.
C ₁₂ H ₁₄ O ₂ -----	Propyl cinnamate-----	190. 11	58	1, 526. 0	6, 392. 4	1, 533. 9	163.
C ₄₈ H ₃₈ O ₁₂ -----	Mannitol hexabenzozoate (s)-----	806. 30	206	5, 358. 5	22, 425. 3	-----	206.

55. PHENOL ESTERS

$$Q = 26.05 \times N + 16.5 - 3.5a - 6.5b + 3.5m$$

C ₁₂ H ₁₄ O ₃ -----	Eugenol acetate (s)-----	206. 11	56	1, 497. 8	6, 268. 3	1, 504. 3	196.
C ₁₂ H ₁₄ O ₃ -----	Isoeugenol acetate (s)-----	206. 11	56	1, 488. 2	6, 228. 1	1, 501. 3	196.
C ₁₃ H ₁₆ O ₃ -----	Phenyl benzoate (s)-----	198. 08	58	1, 510. 5	6, 321. 4	1, 523. 9	183.
C ₁₄ H ₁₂ O ₂ -----	<i>p</i> -Cresyl benzoate (s)-----	212. 10	64	1, 660. 1	6, 947. 5	1, 680. 2	205.
C ₁₄ H ₁₂ O ₄ -----	Guaiacol salicylate (s)-----	244. 10	60	1, 589. 8	6, 653. 3	1, 583. 0	192.
C ₁₅ H ₁₄ O ₂ -----	<i>o</i> -Xylenyl benzoate (s)-----	226. 11	70	1, 814. 3	7, 592. 9	1, 829. 5	205.
C ₁₆ H ₁₆ O ₂ -----	Pseudocumenyl benzoate (s)-----	240. 13	-----	1, 967. 8	8, 235. 2	-----	205.
C ₁₇ H ₁₈ O ₂ -----	Thymyl benzoate (s)-----	254. 14	82	2, 127. 6	8, 904. 0	-----	205.
C ₁₇ H ₁₈ O ₂ -----	Thymyl benzoate (liq.)-----	-----	-----	2, 131. 9	8, 922. 0	2, 142. 1	205.
C ₁₇ H ₁₆ O ₃ -----	Eugenol benzoate (s)-----	268. 13	78	2, 064. 1	8, 638. 3	2, 074. 4	196.
C ₁₇ H ₁₆ O ₃ -----	Isoeugenol benzoate (s)-----	268. 13	78	2, 054. 9	8, 599. 8	2, 071. 4	196.
C ₁₇ H ₁₆ O ₃ -----	Allyl-3,4-guaiacol benzoate (s) (Betel benzoate)-----	268. 13	78	2, 064. 3	8, 639. 1	2, 073. 9	196.
C ₂₀ H ₁₄ O ₄ -----	Resorcylic dibenzoate (s)-----	318. 11	86	2, 237. 0	9, 361. 9	2, 266. 0	205.

56. GLYCEROL ESTERS

C ₁₅ H ₂₀ O ₆ -----	Glyceryl tributyrate-----	302. 21	-----	1, 941. 1	8, 117. 7	-----	215.
C ₁₅ H ₂₀ O ₆ -----	Glyceryl tricyclobutyrate-----	296. 16	-----	1, 844. 9	7, 715. 4	-----	215.
C ₁₈ H ₂₆ O ₆ -----	Glyceryl tricyclovalerate-----	338. 21	-----	2, 308. 6	9, 654. 6	-----	215.
C ₂₄ H ₂₀ O ₆ -----	Glyceryl tribenzoate (s)-----	404. 16	-----	2, 718. 9	11, 378. 6	-----	206.
C ₃₉ H ₇₄ O ₆ -----	Glyceryl trilaurate (s)-----	638. 59	-----	5, 706. 3	23, 880. 9	-----	193; cf. 120.
C ₄₅ H ₈₀ O ₆ -----	Glyceryl trimyristate-----	722. 69	-----	6, 650. 3	27, 831. 5	-----	193; cf. 120.
C ₄₇ H ₈₈ O ₅ -----	Glyceryl dibrassidate (s)-----	732. 70	-----	6, 953. 0	29, 098. 3	-----	193.
C ₄₇ H ₈₈ O ₅ -----	Glyceryl dierucate (s)-----	732. 70	-----	6, 979. 0	29, 207. 1	-----	193.
C ₆₉ H ₁₂₈ O ₆ -----	Glyceryl tribrassidate (s)-----	1, 053. 02	-----	10, 235. 8	42, 836. 8	-----	193.
C ₆₉ H ₁₂₈ O ₆ -----	Glyceryl trierucate (s)-----	1, 053. 02	-----	10, 264. 7	42, 957. 8	-----	193.

VIII. TABLES OF DATA—Continued

3. N COMPOUNDS

57. ALIPHATIC AMINES (PRIMARY)

$$Q = 26.05 \times N + 13\text{ec}$$

Formula	Name	Molec- ular weight	Num- ber of elec- trons (<i>N</i>)	Kg-cal ₁₅ (exper- imental)	Kilo- joules (K. J.)	Kg-cal ₁₅ (calcu- lated to the liquid state)	Literature
CH ₅ N-----	{ Methylamine (g)-----	31.0	9	{ 256.9	1, 074.4	-----	223.
				{ 261.4	1, 092.3	-----	142.
C ₂ H ₇ N-----	Methylamine (liq.)-----	31.05	-----	256.1	1, 071.0	247.4	99, ²⁶
	{ Ethylamine (g)-----	45.0	15	{ 413.1	1, 727.6	-----	223.
	{ Ethylamine (liq.)-----	45.07	-----	408.5	1, 709.6	403.7	99; cf. 15.
C ₂ H ₈ N ₂ .H ₂ O-----	Ethylenediamine-----	78.10	16	452.6	1, 894.1	442.8	19.
C ₃ H ₇ N-----	{ Allylamine (g)-----	57.0	19	{ 528.1	2, 208.6	-----	223.
	{ Allylamine (liq.)-----	57.07	-----	524.8	2, 196.3	521.0	99.
C ₃ H ₉ N-----	{ Propylamine (g)-----	59.0	21	{ 572.3	2, 393.4	-----	223.
	{ Propylamine (liq.)-----	59.08	-----	558.3	2, 336.5	560.1	99.
C ₄ H ₁₁ N-----	<i>n</i> -Butylamine-----	73.10	27	710.6	2, 973.9	716.4	99.
C ₄ H ₁₁ N-----	Isobutylamine-----	73.10	27	713.6	2, 986.4	716.4	99.
C ₄ H ₁₁ N-----	<i>Sec.</i> -Butylamine-----	73.10	27	713.0	2, 983.9	716.4	99.
C ₄ H ₁₁ N-----	<i>Tert.</i> -Butylamine-----	73.10	27	716.0	2, 996.5	716.4	99.
C ₅ H ₁₃ N-----	Isoamylamine-----	87.11	33	866.8	3, 627.6	872.6	99; cf. 143. ²⁷
C ₅ H ₁₁ N-----	1,1-Aminocyclopropylethane	85.10	31	823.3	3, 443.0	833.5	215.
C ₆ H ₁₅ N-----	Hexylamine-----	101.13	39	1, 022.2	4, 277.9	1, 028.9	99.
C ₇ H ₉ N-----	Benzylamine-----	107.08	37	{ 965.8	4, 039.0	973.3	101.
				{ 969.4	4, 054.0	-----	147.
C ₇ H ₁₅ N-----	1-Methylcyclohexylamine-3-	113.13	43	1, 118.7	4, 678.4	1, 133.1	215.
C ₈ H ₁₇ N-----	Heptylamine-----	115.14	45	1, 178.9	4, 933.7	1, 185.3	99.
C ₁₀ H ₁₉ N-----	Camphylamine-----	153.16	59	1, 533.1	6, 416.0	1, 576.9	99.

²⁶ The author (99) used naphthalene to standardize his bomb calorimeter. However, the value he used for naphthalene was 9,665.0 cal./g. The present best value is 9,617.0 cal./g. His values, therefore, ought to be about 0.5 per cent too high, and they have accordingly been corrected by the proper factor. The data are probably not of a high degree of accuracy.

²⁷ See footnote 28.

58. ALIPHATIC AMINES (SECONDARY)

$$Q = 26.05 \times N + 19.5$$

C ₂ H ₇ N-----	{ Dimethylamine (g)-----	45.0	15	{ 418.2	1, 749.4	-----	223.
				{ 426.0	1, 782.8	-----	142.
	{ Dimethylamine (liq)-----	45.07	-----	416.7	1, 743.9	410.2	99.
C ₄ H ₁₁ N-----	{ Diethylamine (g)-----	73.0	27	{ 730.6	3, 057.6	-----	223.
				{ 722.8	3, 024.9	722.9	99.
	{ Diethylamine (liq)-----	73.1	-----	²⁸ 716.9	3, 000.2	-----	143.
C ₆ H ₁₉ N-----	Diisobutylamine-----	129.16	51	1, 348.4	5, 643.1	1, 358.1	99.
C ₆ H ₁₃ N-----	Benzylethylamine-----	135.11	49	1, 289.6	5, 397.1	1, 292.5	99.
C ₁₀ H ₂₃ N-----	Diisoamylamine-----	157.19	63	1, 660.4	6, 948.8	1, 660.5	99.
C ₁₄ H ₁₅ N-----	Dibenzylamine (s)-----	197.13	71	1, 853.0	7, 754.8	1, 869.0	99.

²⁸ Little significance should be attached to values of (143) for the redetermination of the heats of combustion of the three amines by the same author (142) some 25 years later showed enormous variations from the values obtained previously. The values by (142) are, on the whole, too low.

59. ALIPHATIC AMINES (TERTIARY)

$$Q = 26.05 \times N + 26$$

C ₃ H ₉ N-----	{ Trimethylamine (g)-----	59.0	21	{ 579.5	2, 423.5	-----	223.
				{ 592.5	2, 479.6	-----	142; cf. 15.
	{ Trimethylamine (liq)-----	59.08	-----	578.6	2, 421.4	573.1	99.
C ₆ H ₁₅ N-----	Triethylamine-----	101.13	39	²⁹ 1, 036.8	4, 339.0	1, 042.0	99; cf. 143.
C ₁₂ H ₂₇ N-----	Triisobutylamine-----	185.22	75	1, 973.6	8, 259.5	1, 979.8	99.
C ₁₅ H ₃₃ N-----	Triisoamylamine-----	227.37	93	2, 459.3	10, 292.2	2, 448.9	99.
C ₂₁ H ₄₁ N-----	Tribenzylamine (s)-----	287.17	105	2, 762.1	11, 559.4	2, 761.2	99.

²⁹ See footnote 28.

VIII. TABLES OF DATA—Continued

3. N COMPOUNDS—Continued

60. AROMATIC AMINES (PRIMARY)

$$Q = 26.05 \times N + 6.5 - 3.5h - 3.5a - 6.5b$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₆ H ₇ N	Aniline	93.07	31	{ 812.7 811.7 816.7	{ 3,401.2 3,396.9 3,417.9	810.5	182. 99. 211; cf. 184, 147.
C ₆ H ₇ NO	<i>p</i> -Aminophenol (s)	109.07	29	760.0	3,180.6	765.5	97.
C ₆ H ₈ N ₂	<i>p</i> -Phenylenediamine (s)	108.08	32	843.4	3,529.6	839.6	24.
C ₇ H ₉ N	<i>o</i> -Toluidine	107.08	37	964.3	4,032.7	963.3	147.
C ₇ H ₉ N	<i>m</i> -Toluidine	107.08	37	965.3	4,036.9	963.3	147.
C ₇ H ₉ N	<i>p</i> -Toluidine (s)	107.08	37	958.4	4,008.0	963.3	147.
C ₇ H ₉ NO	<i>p</i> -Anisidine (s)	123.08	35	924.0	3,866.9	934.2	99.
C ₈ H ₁₁ N	1-Amino-2,4-xylene	121.10	43	1,108.0	4,637.0	1,116.2	99.
C ₉ H ₁₃ N	Pseudocumidine (s)	135.11	49	1,265.9	5,297.8	1,268.9	99.
C ₁₀ H ₉ N	α -Naphthylamine (s)	143.08	49	1,263.5	5,287.8	1,266.4	99.
C ₁₀ H ₉ N	β -Naphthylamine (s)	143.08	49	1,261.0	5,298.2	1,266.4	99.
C ₁₂ H ₁₂ N ₂	Benzidine (s)	184.12	60	{ 1,556.0 1,560.9	{ 6,511.9 6,532.4	1,562.5	100. 147.
C ₁₂ H ₁₂ N ₂	<i>o,p</i> -Diaminodiphenyl	184.12	60	1,561.8	6,536.1	1,562.5	147.
C ₁₉ H ₁₉ N ₃ O	Triaminotriphenylcarbinol (s). ³⁰	305.18	-----	2,483.5	10,386.0	-----	179.

³⁰ This article also contains the heats of combustion of rosaniline hydrochloride and the hexamethylrosaniline hydrochloride.

61. AROMATIC AMINES (SECONDARY)

$$Q = 26.05 \times N + 13 - 3.5h$$

C ₇ H ₉ N	Methylaniline	107.08	37	973.5	4,071.2	973.3	147; cf. 72.
C ₈ H ₁₁ N	Ethylaniline	121.10	43	1,121.5	4,693.5	1,129.6	99.
C ₁₂ H ₁₁ N	Diphenylamine (s)	169.10	59	{ 1,536.2 1,530.2	{ 6,428.9 6,403.9	1,542.9	182. 99.
C ₁₆ H ₁₃ N	Phenyl- α -naphthylamine (s)	219.11	77	2,003.8	8,382.6	1,998.8	99.
C ₁₆ H ₁₃ N	Phenyl- β -naphthylamine (s)	219.11	77	1,998.0	8,361.6	1,998.8	99.

62. AROMATIC AMINES (TERTIARY)

$$Q = 26.05 \times N + 19.5 - 3.5h$$

C ₈ H ₁₁ N	Dimethylaniline	121.10	43	1,142.7	4,782.4	1,136.1	182.
C ₁₀ H ₁₃ N	Diethylaniline	149.13	55	1,451.6	6,074.9	1,448.7	182.
C ₁₈ H ₁₅ N	Triphenylamine (s)	245.13	87	2,267.8	9,490.7	2,275.3	182.

63. AMINO ACIDS ³¹ (ALIPHATIC)

C ₂ H ₅ NO ₂	Glycine (s)	75.05	9	{ 234.5 233.4	{ 981.4 977.7	-----	194. 241.
C ₃ H ₇ NO ₂	Sarcosine (s) (N-methylglycine).	89.07	15	401.1	1,678.6	-----	195.
C ₃ H ₇ NO ₂	Alanine (s) (α -Aminopropionic acid).	89.07	15	{ 387.7 389.4	{ 1,622.5 1,631.2	-----	94. 66; cf. 23, 64.
C ₃ H ₇ NO ₂	<i>d</i> -l-Alanine (s)	89.07	15	387.5	1,623.2	-----	241.
C ₃ H ₇ NO ₂	<i>d</i> -Alanine (s)	89.07	15	387.5	1,623.2	-----	241.
C ₃ H ₇ NO ₂	Isoserine (s)	105.07	13	343.7	1,439.8	-----	241; cf. 66.

³¹ The general expression $Q = 26.05 \times N + a$ covers this class of compounds adequately. However, since no heat of fusion is available for this class, it is impossible to estimate the value of "a". It is probably 6.5.

VIII. TABLES OF DATA—Continued

3. N COMPOUNDS—Continued

63. AMINO ACIDS (ALIPHATIC)—Continued

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₄ H ₇ NO ₄ -----	Diglycolamidic acid (s)-----	133.07	-----	396.1	1,657.7	-----	198.
C ₄ H ₇ NO ₄ -----	Aspartic acid (s)-----	133.07	-----	384.9	1,610.8	-----	183; cf. 23.
C ₄ H ₇ NO ₄ -----	<i>l</i> -Aspartic acid (s)-----	133.07	-----	385.6	1,615.3	-----	66.
C ₄ H ₈ N ₂ O ₃ -----	Asparagine (s)-----	132.08	-----	383.1	1,601.7	-----	64.
C ₄ H ₈ N ₂ O ₃ H ₂ O-----	Asparagine (cryst)-----	150.10	-----	463.3	1,938.9	-----	194.
C ₄ H ₈ N ₂ O ₃ -----	Glycylglycine (s)-----	132.08	-----	459.7	1,922.0	-----	64.
C ₆ H ₈ N ₂ O ₅ -----	Glycylglycinecarboxylic acid (s)-----	176.08	-----	470.7	1,971.8	-----	66.
C ₆ H ₁₁ NO ₂ -----	<i>dl</i> - α -Aminoisovaleric acid (s) (Valine)-----	117.10	-----	471.3	1,974.3	-----	241; cf. 66.
C ₆ H ₉ NO ₄ -----	Glutamic acid (s) (act.)-----	147.08	-----	700.8	2,935.7	-----	241.
C ₆ H ₉ NO ₆ -----	Triglycolamidic acid (s)-----	191.0	-----	542.4	2,272.1	-----	66; cf. 64.
C ₆ H ₁₀ N ₂ O ₂ -----	Alanine anhydride (s)-----	142.10	-----	559.6	2,341.9	-----	198.
C ₆ H ₁₀ N ₂ O ₂ -----	<i>d</i> -Alanine anhydride (s)-----	142.10	-----	786.4	3,294.2	-----	66.
C ₆ H ₁₁ N ₃ O ₄ -----	Diglycylglycine (s)-----	189.12	-----	786.0	3,292.6	-----	66.
C ₆ H ₁₂ N ₂ O ₃ -----	Glycylglycine ethyl ester (s)-----	160.12	-----	709.8	2,973.4	-----	241.
C ₆ H ₁₃ NO ₂ -----	Leucine (s) (α -aminoisocaproic acid)-----	131.11	-----	803.2	3,364.6	-----	66.
C ₇ H ₁₃ NO ₃ -----	Formyl- <i>d</i> , <i>l</i> -leucine (s)-----	159.11	-----	855.6	3,580.7	-----	194; cf. 66, 23.
C ₈ H ₁₆ N ₂ O ₃ -----	<i>d</i> - <i>l</i> -Leucylglycine (s)-----	188.15	-----	917.4	3,842.9	-----	241.
C ₈ H ₁₄ N ₄ O ₅ -----	Triglycylglycine (s)-----	246.15	-----	1,095.3	4,588.2	-----	241.
C ₉ H ₁₆ N ₂ O ₅ -----	α -Carbethoxyglycylglycine ethyl ester (s)-----	232.15	-----	946.6	3,965.3	-----	66.
C ₉ H ₁₆ N ₂ O ₅ -----	β -Carbethoxyglycylglycine ethyl ester (s)-----	232.15	-----	1,120.4	4,693.4	-----	66.
C ₁₀ H ₁₉ N ₃ O ₄ -----	Leucylglycylglycine (s)-----	245.18	-----	1,091.9	4,573.9	-----	66.
C ₁₂ H ₂₂ N ₂ O ₂ -----	Leucineimide (s) (3,6-diisobutyl-2,5-diacetipiperazine)-----	226.20	-----	1,333.1	5,584.4	-----	66.
			-----	1,723.8	7,220.9	-----	66.

³² See footnote 74b.

64. AMINO ACIDS

(Containing a phenyl radical)

C ₈ H ₉ NO ₂ -----	Phenylglycine (s)-----	151.08	-----	955.1	4,000.9	-----	66.
C ₈ H ₉ NO ₂ -----	Anilidoacetic acid (s)-----	151.08	-----	965.2	4,043.2	-----	66.
C ₉ H ₁₁ NO ₂ -----	Phenylalanine (s)-----	165.10	-----	1,111.3	4,655.2	-----	66.
C ₉ H ₁₁ NO ₃ -----	Tyrosine (s)-----	181.10	-----	1,070.2	4,474.5	-----	64; cf. 23.

65. AMIDES (ALIPHATIC)

$$Q = 26.05 \times N$$

CH ₃ NO-----	Formamide-----	45.03	5	134.9	564.6	-----	209.
CH ₄ N ₂ O-----	Urea (s)-----	60.05	6	151.6	633.8	156.3	64; cf. 194, 42, 92.
C ₂ H ₃ NO ₃ -----	Oxamic acid (s)-----	89.03	5	128.6	537.8	130.2	130. ³³
				132.6	554.9	-----	184.
C ₂ H ₄ N ₂ O ₂ -----	Oxamide (s)-----	88.05	8	203.2	850.4	208.4	184.
C ₂ H ₄ N ₂ O ₂ -----	Formylurea-----	88.05	-----	207.0	865.7	-----	130.
C ₂ H ₅ NO-----	Acetamide (s)-----	59.05	11	282.6	1,182.7	232.5	209.
C ₃ H ₄ N ₂ O ₄ -----	Oxaluric acid (s)-----	132.05	8	207.5	863.4	208.0	130.
C ₃ H ₅ N ₂ O ₃ -----	Methyl oxamate (s)-----	103.05	11	305.4	1,278.1	303.0	184.
C ₃ H ₆ N ₂ O ₂ -----	Malonamide (s)-----	102.07	14	358.8	1,501.6	364.7	184.
C ₃ H ₆ N ₂ O ₂ -----	Acetylurea (s)-----	102.07	14	360.9	1,510.4	364.7	130.
C ₃ H ₆ N ₂ O ₃ -----	Hydantoic acid (s)-----	113.07	12	308.6	1,291.5	312.6	130.
C ₃ H ₇ NO-----	Propionamide (s)-----	105.07	17	439.9	1,840.9	442.8	209.
C ₃ H ₇ NO ₂ -----	Urethane (s)-----	89.07	15	397.2	1,662.3	402.7	184.
C ₃ H ₈ N ₂ O-----	Ethylurea (s)-----	88.08	18	472.0	1,975.3	475.4	130.

³³ The author (130.5) gives the heat of combustion of guanidine nitrate, CH₅N₄O₃.

VIII. TABLES OF DATA—Continued

3. N COMPOUNDS—Continued

65. AMIDES (ALIPHATIC)—Continued

$$Q = 26.05 \times N$$

Formula	Name	Molecular weight	Number of electrons (N)	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₄ H ₇ NO ₃ -----	Ethyl oxamate (s)-----	117.07	17	457.3	1,913.8	459.3	184.
C ₄ H ₇ N ₃ O-----	Creatinine (s)-----	113.08	---	563.4	2,355.6	---	64.
C ₄ H ₈ N ₂ O ₂ -----	Succinamide (s)-----	116.08	20	509.2	2,131.0	521.0	184.
C ₄ H ₈ N ₂ O ₄ -----	<i>d</i> -Tartramide-----	148.08	16	427.0	1,786.9	429.8	54.
C ₄ H ₈ N ₂ O ₄ -----	Mesotartartramide-----	148.08	16	426.6	1,785.3	429.8	54.
C ₄ H ₉ NO-----	<i>n</i> -Butyramide (s)-----	87.08	23	596.0	2,494.3	599.2	209.
C ₄ H ₉ NO-----	Isobutyramide (s)-----	87.08	23	595.9	2,493.8	599.2	209.
C ₄ H ₉ N ₃ O ₂ -----	Creatine (anhydr.) (s)-----	131.10	---	559.8	2,342.8	---	194.
C ₄ H ₉ N ₃ O ₂ .H ₂ O-----	Creatine (cryst)-----	149.12	---	555.4	2,322.1	---	64.
				553.1	2,314.7	---	194.
C ₅ H ₁₀ N ₂ O ₂ -----	Dimethylmalonamide (<i>sym.</i>) (s)-----	130.1	26	685.8	2,870.1	677.3	184.
C ₅ H ₁₁ NO-----	Isovaleramide (s)-----	101.10	29	751.5	3,145.0	755.5	209.
C ₇ H ₁₄ N ₂ O ₂ -----	Diethylmalonamide (s)-----	158.12	38	994.8	4,163.2	989.9	184.
C ₈ H ₁₃ NO-----	Amylpropionamide (s)-----	139.11	43	1,150.4	4,810.9	1,153.2	138.
C ₈ H ₁₆ N ₂ O ₄ -----	<i>d</i> -Tartaricdiethylamide-----	204.14	40	1,064.1	4,453.3	1,068.0	54.
C ₈ H ₁₆ N ₂ O ₄ -----	<i>dl</i> -Tartaricdiethylamide-----	204.14	40	1,064.3	4,454.1	1,068.0	54.
C ₈ H ₁₆ N ₂ O ₄ -----	Mesotartaricdiethylamide-----	204.14	40	1,065.3	4,458.3	1,068.0	54.
C ₉ H ₁₅ NO-----	Hexylpropionamide (s)-----	153.13	49	1,308.0	5,470.1	1,309.5	138.

66. ACID AMIDES (AROMATIC)

$$Q = 26.05 \times N - 3.5\text{hh}$$

C ₇ H ₇ NO-----	Benzamide (s)-----	121.07	33	847.6	3,547.2	856.1	209.
C ₇ H ₇ NO-----	Formanilide (s)-----	121.07	33	861.0	3,603.3	---	209.
C ₇ H ₅ N ₂ O-----	Monophenylurea (s)-----	136.08	34	879.6	3,681.1	882.2	184.
C ₈ H ₉ NO-----	Acetanilide (s)-----	135.03	39	1,010.4	4,228.5	1,012.4	209.
C ₉ H ₇ NO-----	Phenylpropionamide (s)-----	145.06	41	1,095.6	4,531.8	1,094.7	138.
C ₉ H ₉ NO ₃ -----	Hippuric acid (s) (Benzoylglycine)-----	179.08	39	1,012.4	4,236.9	1,018.9	208; cf. 64, 23.
C ₉ H ₁₁ NO-----	Propionanilide (s)-----	149.10	45	1,167.6	4,886.4	1,168.7	209.
C ₁₀ H ₁₁ NO ₃ -----	Benzoylalanine (s)-----	193.10	45	1,168.1	4,888.5	1,175.2	208.
C ₁₀ H ₁₁ NO ₃ -----	Benzoylsarcosine (s)-----	193.10	45	1,179.8	4,937.5	1,175.2	208.
C ₁₀ H ₁₁ NO ₃ -----	<i>o</i> -Toluylglycine (s) ³⁴ -----	193.10	45	1,167.7	4,886.8	1,171.7	208.
C ₁₀ H ₁₁ NO ₃ -----	<i>m</i> -Toluylglycine (s)-----	193.10	45	1,167.0	4,883.9	1,171.7	208.
C ₁₀ H ₁₁ NO ₃ -----	<i>p</i> -Toluylglycine (s)-----	193.10	45	1,167.5	4,885.9	1,171.7	208.
C ₁₀ H ₁₁ NO ₃ -----	Phenaceturic acid (s)-----	193.10	45	1,164.9	4,875.1	1,175.7	208.
C ₁₀ H ₁₁ NO ₄ -----	<i>p</i> -Anisyglycine (s) ³⁵ -----	209.10	43	1,135.2	4,750.8	1,139.6	208.
C ₁₀ H ₁₃ NO ₂ -----	Phenacetin (s)-----	179.11	49	1,285.2	5,378.6	1,289.4	160.
C ₁₁ H ₁₃ NO ₃ -----	<i>o</i> -Toluyllalanine (s)-----	207.11	51	1,321.7	5,531.3	1,328.0	208.
C ₁₁ H ₁₃ NO ₃ -----	<i>p</i> -Toluyllalanine (s)-----	207.11	51	1,319.5	5,522.1	1,328.0	208.
C ₁₃ H ₁₁ NO-----	Benzanilide (s)-----	197.10	61	1,575.5	6,593.5	1,582.1	209.
C ₁₃ H ₁₂ N ₂ O-----	Diphenylurea (s) (<i>sym.</i>)-----	212.12	62	1,612.1	6,746.6	1,608.1	184.
C ₁₃ H ₁₂ N ₂ O-----	Diphenylurea (s) (<i>unsym.</i>)-----	212.12	62	1,614.5	6,756.7	1,608.1	184.
C ₁₆ H ₁₆ N ₂ O ₂ -----	Succinilide (s) (<i>sym.</i>)-----	268.15	76	1,970.4	8,246.1	1,972.8	184.
C ₁₆ H ₁₁ NO ₂ -----	Benzalhippuric acid lactone ³⁶ -----	249.10	---	1,852.1	7,758.5	---	66.
C ₁₆ H ₁₃ NO ₃ -----	Benzalhippuric acid (s) (α-Benzoylaminocinnamic acid) ³⁷ -----	267.11	71	1,848.4	7,742.9	1,852.5	66.
C ₁₆ H ₁₅ NO ₃ -----	Benzoylphenylalanine (s)-----	269.13	73	1,890.1	7,917.6	1,894.0	66.

³⁴ CH₃.C₆H₄.CONH.CH₂.COOH.

³⁵ H₃CO.C₆H₄.CO.NH.CH₂.CO₂H.

³⁶ C₆H₅CO.N—C=CH.C₆H₅.

³⁷ C₆H₅CH : C(CO₂H).HN.OC.C₆H₅.

VIII. TABLES OF DATA—Continued

3. N COMPOUNDS—Continued

67. CYCLIC UREIDES, HYDANTOINS, PYRIMIDINES, PURINES

Formula	Name	Molecular weight	Number of electrons (<i>N</i>)	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₅ H ₂ N ₂ O ₃	Parabanic acid (s) l(Oxaylurea).	114.04	-----	212.4	888.9	-----	130.
C ₃ H ₄ N ₂ O ₂	Hydantoin (s).....	100.05	-----	311.7	1,304.5	-----	130.
C ₄ H ₂ N ₂ O ₄ .H ₂ O	Alloxan (s).....	160.05	-----	276.3	1,156.3	-----	130.
C ₄ H ₄ N ₂ O ₃	Barbituric acid (s).....	128.05	-----	358.7	1,501.2	-----	66; cf. 130.
C ₄ H ₂ N ₂ O ₃	Aminobarbituric acid (s).....	143.07	-----	379.1	1,586.5	-----	130.
C ₄ H ₆ N ₄ O ₃	Allantoin (s) ³⁸	158.09	-----	413.5	1,730.5	-----	130.
C ₅ H ₄ N ₄ O.....	Hypoxanthine (s) (6-Oxypurine).	136.06	-----	408.1	1,706.3	-----	64.
C ₅ H ₄ N ₄ O.....	8-Oxypurine (s).....	136.06	-----	821.0	3,435.9	-----	19.
C ₅ H ₄ N ₄ O.....	Xanthine (s) (2,6-Diooxypurine).	152.07	-----	591.8	2,476.7	-----	19.
C ₅ H ₄ N ₄ O.....	Xanthine (s) (2,6-Diooxypurine).	152.07	-----	514.6	2,153.6	-----	24.
C ₅ H ₄ N ₄ O ₃	Uric acid (s) ³⁹	168.07	-----	460.2	1,925.9	-----	194; cf. 130, 64.
C ₅ H ₅ N ₅ O.....	Guanine (s).....	151.01	-----	586.4	2,454.1	-----	194.
C ₅ H ₅ N ₂ O.....	4-Methyluracil (s).....	126.07	-----	566.1	2,371.6	-----	241; cf. 66.
C ₅ H ₅ N ₂ O.....	5-Methyluracil (s) (Natural "thymus").	126.07	-----	564.8	2,366.1	-----	66.
C ₅ H ₅ N ₂ O ₃	Dimethylparabanic acid (s).....	142.07	-----	538.3	2,252.8	-----	130.
C ₅ H ₅ N ₄ O.....	Pseudouric acid (s).....	186.10	-----	454.2	1,900.8	-----	130.
C ₅ H ₅ N ₂ O.....	4-Methylhydrouracil (s).....	128.08	-----	618.2	2,589.8	-----	66.
C ₅ H ₅ N ₄	7-Methylpurine (s).....	134.08	-----	821.0	3,435.9	-----	19.
C ₅ H ₅ N ₄ O.....	7-Methylhypoxanthine (s).....	150.08	-----	759.9	3,180.2	-----	19.
C ₇ H ₅ N ₄ O.....	Theobromine (s) (3,7-Dimethyl-2,6-dihydroxypurine).	180.11	-----	845.3	3,537.6	-----	130.
C ₈ H ₆ N ₄ O ₃ .2H ₂ O	Alloxanthine (s).....	322.12	-----	583.9	2,443.6	-----	130.
C ₈ H ₆ N ₆ O.....	Murexide (s).....	284.12	-----	735.9	3,079.7	-----	130.
C ₈ H ₁₀ N ₄ O.....	Caffeine (s) (1,3,7-Trimethylxanthine) .	194.12	-----	1,014.2	4,244.4	-----	194.
C ₈ H ₁₂ N ₂ O ₃	Veronal (s).....	184.12	-----	983.1	4,113.3	-----	66.
C ₁₀ H ₈ N ₂ O.....	4-Phenyluracil (s).....	188.08	-----	1,131.0	4,737.8	-----	66.
C ₁₂ H ₈ N ₄ O ₆	Desoxyamalic acid (s).....	310.14	-----	1,322.1	5,533.0	-----	130.
C ₁₂ H ₁₄ N ₄ O ₈	Tetramethylalloxanthine (s) (Amalic acid).	342.15	-----	1,239.3	5,186.5	-----	130.

³⁸ The author (130) gives the heat of combustion of methylallantoin, C₅H₅N₄O₃. Note, however, that the analysis for nitrogen shows a wide divergence from the calculated value. The values of (130) are open to serious objections in that he used camphor to aid in the combustion of the substance. No great reliance should be attached to any of his values.

³⁹ The author (130) gives also the heat of combustion of ammonium urate, C₅H₇N₅O₃.

68. RING NITROGEN COMPOUNDS

C ₄ H ₅ N.....	Pyrrole.....	67.05	-----	567.7	2,375.8	-----	24.
C ₄ H ₆ N ₂ O.....	Diketopiperazine (s) (Glycine anhydride).	114.07	-----	474.6	1,988.1	-----	241; cf. 66.
C ₅ H ₅ N.....	Pyridine.....	79.05	-----	658.5	2,755.8	-----	53.
C ₅ H ₁₁ N.....	Piperidine.....	85.10	-----	664.8	2,782.2	-----	57.
C ₅ H ₁₂ N.....	Hexamethylenetetramine (s).	140.14	-----	826.6	3,459.3	-----	57.
C ₆ H ₇ N.....	α -Picoline.....	93.07	-----	1,006.7	4,213.0	-----	55.
C ₆ H ₇ N.....	β -Picoline.....	93.07	-----	815.2	3,411.6	-----	53.
C ₆ H ₇ N.....	γ -Picoline.....	93.07	-----	812.2	3,399.1	-----	53.
C ₆ H ₇ N.....	Lutidine ⁴⁰ (Dimethylpyridine).	107.08	-----	815.8	3,414.1	-----	53.
C ₈ H ₅ NO.....	Isatin (s) ⁴¹	147.05	-----	968.0	4,051.1	-----	53.
C ₈ H ₇ N.....	Indole (s).....	117.07	-----	867.8	3,631.7	-----	1.
C ₈ H ₇ NO.....	Dioxindol (s).....	149.07	-----	1,022.2	4,277.9	-----	24.
C ₉ H ₁₁ N.....	Tetrahydroquinoline.....	135.11	-----	915.7	3,832.2	-----	1.
C ₉ H ₁₁ N.....	Tetrahydroquinoline.....	135.11	-----	1,228.7	5,142.1	-----	57.

⁴⁰ The exact isomer not designated in article.

⁴¹ The author (1) gives also the heat of combustion of isatide, C₁₀H₁₂N₂O₄, obtained by reducing isatin with zinc dust in acid solution, as 1,777.8 kg-cal₁₅ per mole.

VIII. TABLES OF DATA—Continued

3. N COMPOUNDS—Continued

68. RING NITROGEN COMPOUNDS—Continued

Formula	Name	Molecular weight	Number of electrons (<i>N</i>)	Kg-cal. ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal. ₁₅ (calculated to the liquid state)	Literature
C ₈ H ₇ N	Skatole (3-Methylindole)	131.08	-----	1, 170.5	4, 898.5	-----	24.
C ₉ H ₉ N	α-Methylindole	131.08	-----	1, 168.7	4, 891.0	-----	24.
C ₉ H ₇ N	Quinoline	129.06	-----	1, 123.5	4, 701.9	-----	57.
C ₁₀ H ₉ N	Phenylpyrrole (s)	143.08	-----	1, 283.5	5, 371.5	-----	183.
C ₁₀ H ₉ N	Quinaldine (α-Methylquinoline)	143.08	-----	1, 287.7	5, 389.0	-----	57.
C ₁₀ H ₉ NO ₄	Opianic acid oxime anhydride (s)	207.08	-----	1, 151.4	4, 818.6	-----	183; cf. 161.
C ₁₀ H ₁₃ N	Tetrahydroquinaldine	147.11	-----	1, 382.1	5, 784.1	-----	57.
C ₁₂ H ₉ N	Carbazole (s)	167.08	-----	1, 475.0	6, 172.9	-----	24.
C ₁₅ H ₁₀ N ₂ O ₂	Indigo (s)	262.10	-----	1, 815.0	7, 595.8	-----	1.
C ₂₀ H ₂₇ NO ₁₁	Amygdalin (s)	457.2	-----	2, 348.4	9, 828.0	-----	19.

69. RING NITROGEN COMPOUNDS, IMIDES

$$Q = 26.05 \times N - 3.5hh$$

C ₄ H ₅ NO ₂	Succinimide (s)	99.05	17	437.9	1, 832.6	442.8	184; cf. 27.
C ₅ H ₇ NO ₄	<i>dl</i> -N-Methyltartramide (s)	145.06	19	516.5	2, 161.6	514.4	231.
C ₅ H ₉ NO ₄	<i>d</i> -N-Ethyltartramide (s)	159.08	25	671.1	2, 808.6	670.7	231.
C ₅ H ₉ NO ₄	<i>dl</i> -N-Ethyltartramide (s)	159.08	25	671.2	2, 809.0	670.7	231.
C ₆ H ₉ NO ₄	N-Ethylmesotartramide (s)	159.08	25	672.7	2, 811.9	670.7	231.
C ₈ H ₅ NO ₂	Phthalimide (s)	147.05	33	849.5	3, 555.2	852.6	184.
C ₁₀ H ₉ NO ₄	Hemipinimide (s)	207.08	-----	1, 099.0	4, 599.3	-----	108; cf. 161.
C ₁₀ H ₉ NO ₄	<i>d</i> -N-Phenyltartramide	207.08	41	1, 085.7	4, 543.7	1, 077.6	231.
C ₁₀ H ₉ NO ₄	<i>dl</i> -N-Phenyltartramide	207.08	41	1, 085.9	4, 544.5	1, 077.6	231.
C ₁₁ H ₁₁ NO ₄	<i>d</i> -N-Benzyltartramide (s)	221.10	47	1, 237.8	5, 180.2	1, 240.3	231.
C ₁₁ H ₁₁ NO ₄	<i>dl</i> -N-Benzyltartramide (s)	221.10	47	1, 237.7	5, 179.8	1, 240.3	231.
C ₁₁ H ₁₁ NO ₄	N-Benzylmesotartramide (s)	221.10	47	1, 240.7	5, 192.3	1, 240.3	231.

70. ALKALOIDS

(Pyridine, Piperidine, Quinoline, and Isoquinoline)

C ₈ H ₁₇ N	Coniine	127.14	-----	1, 275.5	5, 334.1	-----	19.
C ₁₀ H ₁₄ N ₂	Nicotine	162.13	-----	1, 427.7	5, 974.9	-----	24.
C ₁₇ H ₁₉ NO ₃ ·H ₂ O	Morphine (s)	308.18	-----	2, 146.3	8, 975.8	-----	106.
C ₁₈ H ₂₁ NO ₃ ·H ₂ O	Cocaine (s)	317.20	-----	2, 327.6	9, 734.0	-----	106.
C ₁₉ H ₂₁ NO ₃	Thebaine (s)	311.18	-----	2, 441.3	10, 209.5	-----	106.
C ₂₀ H ₂₁ NO ₄	Papaverine (s)	339.18	-----	2, 478.1	10, 363.4	-----	106.
C ₂₁ H ₂₂ N ₂ O ₂	Strychnine (s)	334.20	-----	2, 685.7	11, 239.7	-----	28.
C ₂₂ H ₂₃ NO ₇	Narcotine (s)	413.20	-----	2, 644.5	11, 059.3	-----	106.
C ₂₃ H ₂₆ N ₂ O ₄	Brucine (s)	394.23	-----	2, 933.0	12, 274.6	-----	28.
C ₂₃ H ₂₇ NO ₈ ·2H ₂ O	Narceine (s)	481.27	-----	2, 802.9	11, 721.7	-----	106.

71. ALIPHATIC NITRILES

$$Q = 26.05 \times N + 16.5$$

C ₂ N ₂	Cyanogen (g)	52.0	8	258.3	1, 080.2	-----	223.
C ₂ H ₃ N	Acetonitrile (v)	41.0	-----	262.1	1, 066.9	-----	10.
C ₂ H ₃ N	Acetonitrile (liq)	41.03	11	310.4	1, 298.1	-----	223.
C ₂ H ₃ NO	Glycollic nitrile	41.03	11	302.4	1, 265.5	-----	102.
		57.03	11	256.7	1, 074.3	257.4	24.
C ₃ H ₂ N ₂	Malononitrile (s)	84.05	14	394.8	1, 652.2	397.7	41.
C ₃ H ₃ NO ₂	Cyanoacetic acid (s)	85.03	11	298.8	1, 250.5	303.0	78.
C ₃ H ₄ N ₂ O	Cyanoacetamide (s)	84.05	14	376.3	1, 574.8	381.2	78.
C ₃ H ₅ N	Propionitrile	55.05	17	456.4	1, 910.0	459.3	102.
C ₃ H ₅ NO	Ethylidene lactonitrile (aldehyde cyanhydrin)	71.05	15	421.1	1, 762.3	420.2	24.

VIII. TABLES OF DATA—Continued

3. N COMPOUNDS—Continued

71. ALIPHATIC NITRILES—Continued

$$Q = 26.05 \times N + 16.5$$

Formula	Name	Molecular weight	Number of electrons	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₄ N ₂ -----	Carbon subnitride (s) (acetylenedicarboxylic acid nitrile).	76.0	16	⁴² 514.8	2,152.9	482.9	139.
C ₄ H ₄ N ₂ -----	Succinic acid nitrile-----	80.04	20	545.7	2,283.7	554.0	41.
C ₄ H ₅ N-----	Allyl cyanide-----	67.05	21	574.9	2,406.0	576.6	51.
C ₄ H ₅ N-----	Trimethylene nitrile-----	67.05	21	581.5	2,433.6	576.6	51.
C ₄ H ₅ N-----	Crotononitrile-----	67.05	21	571.9	2,393.4	576.6	51.
C ₄ H ₅ N-----	Isocrotononitrile-----	67.05	21	573.8	2,401.4	576.6	51.
C ₄ H ₅ NO ₂ -----	Methyl cyanoacetate-----	99.05	17	471.6	1,973.7	475.8	78.
C ₄ H ₅ N ₃ -----	Diglycolamidic nitrile (di-(cyanomethyl)amine). ⁴³	95.07	-----	590.6	2,471.7	-----	198.
C ₄ H ₇ N-----	<i>n</i> -Butyronitrile-----	69.07	23	613.3	2,566.7	615.6	102.
C ₅ H ₆ N ₂ -----	Glutaric nitrile (s)-----	94.07	26	699.6	2,927.8	710.3	41.
C ₅ H ₇ NO ₂ -----	Ethyl cyanoacetate-----	113.07	23	630.0	2,636.6	635.1	78.
C ₅ H ₇ N-----	Isovaleronitrile-----	83.08	29	772.1	3,231.2	771.9	102.
C ₅ H ₆ N ₄ -----	Triglycolamidic nitrile (tri-(cyanomethyl)amine). ⁴⁴	134.09	-----	846.0	3,540.5	-----	198.
C ₆ H ₇ NO ₃ -----	Methyl acetylcynoacetate (s).	141.07	25	685.0	2,866.7	693.7	78.
C ₆ H ₉ NO ₂ -----	Propyl cyanoacetate-----	127.08	29	789.0	3,301.9	791.4	78.
C ₇ H ₉ NO ₃ -----	Ethyl cyanoacetylacetate (s).	155.08	31	836.6	3,501.2	850.0	78.
C ₈ H ₁₁ N-----	Amyl propiolic nitrile-----	121.09	43	1,164.2	4,868.7	1,169.7	138.
C ₁₁ H ₁₅ NO-----	Cyanocamphor (s)-----	177.05	57	1,495.4	6,258.3	1,507.3	42.

⁴² The above value represents the result of a single determination and should be considered merely as an approximate value.

⁴³ Considerable difficulty was experienced in the combustion of the compound due to its explosive character.

⁴⁴ $N \equiv (CH_2C \equiv N)_3$.

72. AROMATIC NITRILES

$$Q = 26.05 \times N + 16.5nn - 6.5pp$$

C ₇ H ₅ N-----	Benzonitrile-----	103.05	33	865.5	3,622.1	869.6	41.
C ₈ H ₇ N-----	Benzyl cyanide-----	117.07	39	1,023.5	4,283.4	1,029.4	41.
C ₈ H ₇ N-----	<i>o</i> -Tolunitrile-----	117.07	39	1,030.3	4,311.8	1,022.4	41.
C ₈ H ₅ NO-----	Benzoyl cyanide (s)-----	131.05	35	940.2	3,934.7	⁴⁵ 937.7	78.
C ₉ H ₇ NO-----	Cyanoacetophenone (s)-----	145.07	-----	1,085.6	4,543.2	-----	78.
C ₉ H ₅ N-----	Phenylpropiolic nitrile-----	127.04	41	1,117.8	4,674.6	1,111.2	138.
C ₁₀ H ₇ N-----	α -Naphthonitrile (s)-----	153.07	51	1,326.2	5,550.2	1,325.5	102.
C ₁₁ H ₇ N-----	β -Naphthonitrile (s)-----	153.07	51	1,321.0	5,528.4	1,325.5	102.

⁴⁵ See formula for ketonic acids.

73. CARBYLAMINES

(Aliphatic)

$$Q = 26.05 \times N + 33.1$$

C ₂ H ₅ N-----	Methyl carbylamine-----	41.03	11	{ 317.4 320.1 477.1 480.5	{ 1,328.3 1,339.6 1,996.7 2,010.9	{ 319.6 ----- 475.9 -----	{ 98. 77. 77. 77.
C ₃ H ₅ N-----	Ethyl carbylamine-----	55.05	17				
C ₄ H ₅ N-----	Allyl carbylamine-----	67.05	21	609.1	2,549.1	593.1	77.
C ₄ H ₇ N-----	Propyl carbylamine-----	69.06	23	639.6	2,676.7	632.2	77.
C ₆ H ₇ N-----	Isobutyl carbylamine-----	83.08	29	796.0	3,331.3	788.3	77.
C ₆ H ₁₁ N-----	Isoamyl carbylamine-----	97.10	35	949.5	3,973.7	944.8	77.
C ₈ H ₇ N-----	Benzyl carbylamine-----	117.07	39	1,046.5	4,379.6	1,045.5	77. ⁴⁶

⁴⁶ The same article contains also the heats of combustion of double compounds of silver cyanide with methyl, ethyl, propyl, isobutyl, isoamyl carbylamines, C₃H₅N₂Ag to C₇H₁₁N₂Ag. The heats of combustion of these compounds are, within the limits of experimental error, rather uniformly about 503 kilojoules larger than the values for the carbylamines.

VIII. TABLES OF DATA—Continued

3. N COMPOUNDS—Continued

74. ISOCYANATES

(Aliphatic)

$$Q = 26.05 \times N + 33.1$$

Formula	Name	Molecular weight	Number of electrons	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₂ H ₅ NO-----	Methyl isocyanate-----	57.03	9	269.4	1,127.4	267.6	96.
C ₃ H ₇ NO-----	Ethyl isocyanate-----	71.05	15	424.5	1,776.5	423.9	96.

75. HYDROXYLAMINE DERIVATIVES

C ₆ H ₇ NO-----	Phenylhydroxylamine ⁴⁷ -----	109.06	-----	803.7	3,366.7	-----	163.
C ₆ H ₅ N ₂ O ₃ -----	<i>m</i> -Nitrophenylhydroxylamine	154.06	-----	765.6	3,204.0	-----	164.

⁴⁷ The author (163) does not indicate which isomer is burned.

76. ALIPHATIC NITRO COMPOUNDS

$$Q = 26.05 \times N + 13$$

CH ₃ NO ₂ -----	Nitromethane-----	61.03	6	169.4	708.4	169.3	212; cf. 36.
C ₂ H ₅ NO ₂ -----	Nitroethane-----	75.05	12	322.2	1,348.4	325.6	36.
C ₃ H ₇ NO ₂ -----	Nitropropane-----	89.07	18	477.9	1,998.6	481.9	212.
C ₁₀ H ₁₅ NO ₃ -----	α -Nitrocamphor (s)-----	197.13	-----	1,371.1	5,738.1	-----	42. ⁴⁸

⁴⁸ This article contains also the heat of combustion of other forms of nitrocamphor.

77. AROMATIC NITRO COMPOUNDS ⁴⁹

$$Q = 26.05 \times N + 13.55$$

C ₆ H ₅ NO ₂ -----	Nitrobenzene-----	123.05	28	{ 739.2 732.4	{ 3,091.3 3,062.9	{ 742.4 -----	{ 72. 211.
C ₆ H ₄ N ₂ O ₄ -----	<i>o</i> -Dinitrobenzene (s)-----	168.05	26	{ 703.2 695.1	{ 2,942.9 2,908.9	{ 703.3 703.3	{ 33; cf. 72. 33.
C ₆ H ₄ N ₂ O ₄ -----	<i>p</i> -Dinitrobenzene (s)-----	168.05	26	{ 692.0 696.8	{ 2,893.9 2,916.1	{ ----- 703.3	{ ----- 33.
C ₆ H ₄ N ₂ O ₄ -----	<i>m</i> -Dinitrobenzene (s) ⁵⁰ -----	168.05	26	{ 694.7 663.7	{ 2,905.2 2,777.6	{ ----- 664.2	{ 211; cf. 72. 33; cf. 72.
C ₆ H ₃ N ₃ O ₆ -----	1,3,5-Trinitrobenzene (s)-----	213.05	24	673.7	2,817.4	664.7	72.
C ₆ H ₃ N ₃ O ₆ -----	1,2,4-Trinitrobenzene (s)-----	213.05	24	673.7	2,817.4	664.7	72.
C ₁₉ H ₁₃ N ₃ O ₈ -----	Trinitrotriphenylmethane(s)-----	379.13	86	2,271.5	9,499.4	2,279.3	179.
C ₁₉ H ₁₃ N ₃ O ₇ -----	Trinitrotriphenyl carbinol(s)-----	395.13	84	2,216.7	9,270.2	2,230.7	179.

⁴⁹ The heats of combustion of 1,3,5-trinitrobenzene, 2,4,6-trinitro-1-methylnitroaminobenzene, C₇H₅N₃O₈, 2,4,6-trinitrotoluene, C₇H₅N₃O₈, 2,3,4,6-tetranitro-1-methylnitroaminobenzene, C₇H₄N₆O₁₀, ammonium picrate, C₆H₅N₄O₇, ammonium salt of hexanitrodiphenylamine, C₁₂H₈N₈O₁₂, and trinitroethane, C₂H₃N₃O₇, used as explosives, are given by Rubtsov and Sever'yanov, J. Russ. Phys. Chem. Soc., 50, p. 140; 1918. However, the results are valueless as far as accuracy is concerned, and, since the data in regard to the methods employed are entirely missing, the values have been omitted from this report.

⁵⁰ The author (148) claims that by mixing *m*-dinitrobenzene and naphthalene no heat is evolved. Certainly the lower heat of combustion 0.13 per cent obtained for the mixture is meaningless for individual determinations do not check better than 0.5 to 1 per cent.

VIII. TABLES OF DATA—Continued

3. N COMPOUNDS—Continued

78. SUBSTITUTED AROMATIC NITRO COMPOUNDS

$$Q = 26.05 \times N + 13ss - 3.5a$$

Formula	Name	Molecular weight	Number of electrons	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₇ H ₇ NO ₂ -----	<i>o</i> -Nitrotoluene-----	137.06	34	897.0	3,751.3	895.2	72.
C ₇ H ₇ NO ₂ -----	<i>p</i> -Nitrotoluene (s)-----	137.06	34	888.6	3,716.1	895.2	72.
C ₇ H ₇ NO ₂ -----	<i>m</i> -Nitrotoluene-----	137.06	34	892.9	3,734.1	895.2	72.
C ₇ H ₆ N ₂ O ₄ -----	2,3-Dinitrotoluene (s)-----	182.06	32	889.9	3,721.6	856.1	211.
C ₇ H ₆ N ₂ O ₄ -----	2,3-Dinitrotoluene (s)-----	182.06	32	859.6	3,594.9	856.1	211.
C ₇ H ₆ N ₂ O ₄ -----	2,4-Dinitrotoluene (s)-----	182.06	32	852.8	3,566.4	856.1	211.
C ₇ H ₆ N ₂ O ₄ -----	2,5-Dinitrotoluene (s)-----	182.06	32	855.2	3,576.5	856.1	72.
C ₇ H ₆ N ₂ O ₄ -----	2,6-Dinitrotoluene (s)-----	182.06	32	854.3	3,572.7	856.1	72.
C ₇ H ₆ N ₂ O ₄ -----	3,4-Dinitrotoluene (s)-----	182.06	32	859.9	3,596.1	856.1	72.
C ₇ H ₆ N ₂ O ₄ -----	3,5-Dinitrotoluene (s)-----	182.06	32	853.0	3,567.3	856.1	72.
C ₇ H ₅ N ₃ O ₆ -----	2,4,6-Trinitrotoluene (s)-----	227.06	30	820.7	3,432.2	817.0	72.
C ₇ H ₅ N ₃ O ₆ -----	2,3,4-Trinitrotoluene (s)-----	227.06	30	832.9	3,483.2	817.0	72.
C ₇ H ₅ N ₃ O ₆ -----	3,4,6-Trinitrotoluene (s)-----	227.06	30	825.6	3,452.7	817.0	72.
C ₇ H ₅ N ₃ O ₆ -----	3,4,5-Trinitrotoluene (s)-----	227.06	30	828.1	3,463.1	817.0	72.
C ₇ H ₅ N ₃ O ₆ -----	2,3,5-Trinitrotoluene (s)-----	227.06	30	823.8	3,445.1	817.0	72.
C ₇ H ₅ N ₃ O ₆ -----	2,3,6-Trinitrotoluene (s)-----	227.06	30	825.3	3,451.4	817.0	72.
C ₈ H ₆ N ₂ O ₄ -----	<i>m</i> - β -Dinitrostyrene (s)-----	194.06	36	957.4	4,006.7	970.3	226.
C ₈ H ₆ N ₂ O ₄ -----	<i>p</i> - β -Dinitrostyrene (s)-----	194.06	36	962.6	4,028.5	970.3	226.
C ₈ H ₁₁ NO ₂ -----	Nitromesitylene (s)-----	165.10	46	1,204.7	5,038.1	1,200.8	243. ⁸¹
C ₈ H ₁₁ NO ₂ -----	ω -Nitromesitylene (s)-----	165.10	46	1,194.3	4,994.6	1,208.0	243.
C ₉ H ₁₀ N ₂ O ₄ -----	Dinitromesitylene (s)-----	210.10	44	1,175.7	4,916.8	1,161.7	243.
C ₉ H ₁₀ N ₂ O ₄ -----	ω - <i>o</i> -Dinitromesitylene-----	210.10	44	⁸² 1,155.7	4,830.8	1,161.7	243.
C ₁₄ H ₉ NO ₄ -----	<i>p</i> -Nitrobenzil (s)-----	255.08	60	1,600.9	6,699.8	1,589.0	8. ⁸³
C ₁₆ H ₁₁ NO ₅ -----	<i>p</i> -Nitroacetylbenzoin (s)-----	297.10	70	1,864.3	7,802.1	1,852.5	8.
C ₂₁ H ₁₃ NO ₅ -----	<i>p</i> -Nitrobenzoylbenzoin (s)-----	359.11	92	2,443.4	10,225.6	2,422.1	8.

⁸¹ All the values by (243) have been corrected according to the method suggested by Swietoslawski, J. Amer. Chem. Soc., 42, p. 1091; 1920.

⁸² The author (243) believes that the difference in the heats of combustion of these two isomers, 1.79 per cent, is due to the fact that the compounds were not quite pure.

⁸³ Details as to procedure employed in obtaining the data are completely lacking in the paper.

79. AROMATIC NITROPHENOLS, PHENETOLES, NITRANILINES, NITROACETANILIDES

$$Q = 26.05 \times N + 13ss + 3.5m + 6.5j + 13kk + 19.5p$$

C ₆ H ₅ NO ₃ -----	<i>o</i> -Nitrophenol (s)-----	139.05	26	{ 689.1 687.9 688.3	{ 2,881.8 2,878.9 2,880.5	{ 693.8 ----- -----	{ 72. 131. 210.
C ₆ H ₅ NO ₃ -----	<i>m</i> -Nitrophenol (s)-----	139.05	26	{ 684.4 686.2 688.8	{ 2,864.2 2,869.7 2,882.6	{ 693.8 693.8 -----	{ 210. 72. 131.
C ₆ H ₅ NO ₃ -----	<i>p</i> -Nitrophenol (s)-----	139.05	26	{ 688.2 688.2 688.2	{ 2,880.1 2,880.1 2,880.1	{ ----- ----- -----	{ 210. ----- -----
C ₆ H ₄ N ₂ O ₅ -----	2,4-Dinitrophenol (s)-----	184.05	24	648.0	2,709.9	654.7	72.
C ₆ H ₃ N ₃ O ₇ -----	2,4,6-Trinitrophenol (s) (Picric acid).-----	229.05	22	{ 621.1 611.8	{ 2,597.4 2,562.8	{ 615.6 -----	{ 72. 170.
C ₆ H ₅ NO ₃ -----	<i>o</i> -Nitrophenetole-----	167.08	38	1,021.2	4,270.7	1,022.4	211.
C ₆ H ₅ NO ₃ -----	<i>m</i> -Nitrophenetole-----	167.08	38	1,009.2	4,223.5	1,022.4	210.
C ₆ H ₅ N ₂ O ₅ -----	<i>p</i> -Nitrophenetole-----	167.08	38	1,006.0	4,210.1	1,022.4	210.
C ₆ H ₆ N ₂ O ₅ -----	<i>o</i> -Nitraniiline (s)-----	138.06	29	765.8	3,204.8	771.4	210.
C ₆ H ₆ N ₂ O ₅ -----	<i>m</i> -Nitraniiline (s)-----	138.06	29	765.2	3,200.1	771.4	211.
C ₆ H ₆ N ₂ O ₅ -----	<i>p</i> -Nitraniiline (s)-----	138.06	29	761.0	3,187.8	771.4	170.
C ₇ H ₈ N ₂ O ₅ -----	<i>p</i> -Nitromethylaniline (s)-----	152.08	35	924.3	3,865.4	934.3	72.
C ₇ H ₇ N ₃ O ₄ -----	2,4-Dinitromethylaniline (s)-----	197.08	33	884.5	3,698.9	895.2	72.
C ₇ H ₆ N ₄ O ₆ -----	2,4,6-Trinitromethylaniline (s)-----	242.08	31	857.9	3,587.7	856.0	72.
C ₇ H ₅ N ₆ O ₈ -----	Tetryl (s)-----	287.08	-----	842.3	3,522.5	-----	72.
C ₈ H ₇ N ₆ O ₈ -----	Methyltetryl (s) (2,4,6-Trinitro- <i>N</i> -nitroethylaniline).-----	301.10	-----	1,009.3	4,220.9	-----	72.
C ₈ H ₈ N ₂ O ₅ -----	<i>o</i> -Nitroacetanilide (s)-----	180.08	37	973.9	4,075.8	973.3	210.
C ₈ H ₈ N ₂ O ₅ -----	<i>m</i> -Nitroacetanilide (s)-----	180.08	37	969.5	4,054.5	973.3	211; cf. 131.
C ₈ H ₈ N ₂ O ₅ -----	<i>p</i> -Nitroacetanilide (s)-----	180.08	37	968.2	4,051.9	973.3	210.

VIII. TABLES OF DATA—Continued

3. N COMPOUNDS—Continued

80. AROMATIC NITROALDEHYDES

$$Q = 26.05 \times N + 13ss + 13r - 3.5a$$

Formula	Name	Molecular weight	Number of electrons	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₇ H ₅ NO ₃ -----	<i>m</i> -Nitrobenzaldehyde (s)-----	151.05	30	800.4	3,349.7	804.0	131.

81. AROMATIC NITRO ACIDS

$$Q = 26.05 \times N + 13ss - 3.5a + 13c$$

C ₇ H ₅ NO ₄ -----	<i>o</i> -Nitrobenzoic acid (s)-----	167.05	28	{ 729.8 735.0	{ 3,054.2 3,078.9	738.9	131.
C ₇ H ₅ NO ₄ -----	<i>m</i> -Nitrobenzoic acid (s)-----	167.05	28	{ 726.4 729.1	{ 3,039.9 3,049.1	738.9	58. 151.
C ₇ H ₅ NO ₄ -----	<i>p</i> -Nitrobenzoic acid (s)-----	167.05	28	{ 728.3 728.3	{ 3,047.9 3,045.8	738.9	58. 151.
C ₉ H ₇ NO ₄ -----	<i>o</i> -Nitrocinnamic acid (s)-----	193.06	38	999.0	4,180.8	1,009.4	226.
C ₉ H ₇ NO ₄ -----	<i>m</i> -Nitrocinnamic acid (s)-----	193.06	38	995.6	4,166.6	1,009.4	226.
C ₉ H ₇ NO ₄ -----	<i>p</i> -Nitrocinnamic acid (s)-----	193.06	38	996.5	4,170.4	1,009.4	226.

82. PHENYLHYDRAZONES AND OSAZONES

The two articles by Ph. Landrieu, *Compt. rend.*, **141**, p. 358; 1905; **142**, p. 540; 1906, contain the heats of combustion of the phenylhydrazones of the following aldehydes and ketones: Acetaldehyde, acetone, diacetyl, furfuraldehyde, benzaldehyde, salicylaldehyde, acetophenone, anisaldehyde, benzophenone, benzoin, benzil; the phenylhydrazones of the following sugars: Arabinose, glucose, galactose, levulose, mannose, maltose, lactose; the osazones of glyoxal, diacetyl, benzil; and of the following sugars: Arabinose, xylose, glucose, levulose, mannose, galactose, maltose, lactose. The data are not included in the tables, for the information given in the above articles in regard to the work is extremely meager, and a careful analysis of the values indicates that they do not form a homogeneous series.

83. ALDOXIMES (ALIPHATIC)

C ₂ H ₅ NO-----	Aldoxime (s)-----	59.05	-----	340.6	1,424.4	-----	93. ⁵⁴
C ₃ H ₇ NO-----	Acetoxime (s)-----	73.07	-----	490.5	2,051.3	-----	93.

⁵⁴ It is of interest to compare these values of (93) with those of (215) for methyl ethyl ketoxime, C₄H₉NO. The former's values appear to be about 0.8 per cent too high.

84. KETOXIMES (ALIPHATIC)

C ₄ H ₉ NO-----	Methyl ethyl ketoxime-----	87.08	-----	{ 646.5 651.0	{ 2,703.7 2,724.4	-----	215. 93.
C ₉ H ₁₇ NO-----	Cycloheptyl methyl ketoxime (s)-----	155.15	-----	1,363.5	5,702.2	-----	215.
C ₁₀ H ₁₇ NO-----	Camphoroxime (s)-----	167.15	-----	1,480.8	6,197.2	-----	93.

VIII. TABLES OF DATA—Continued

3. N COMPOUNDS—Continued

85. AROMATIC ALDOXIMES AND KETOXIMES

Formula	Name	Molecular weight	Number of electrons	Kg-cal. ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal. ₁₅ (calculated to the liquid state)	Literature
C ₆ H ₆ NO ₂ -----	Benzoquinone oxime (<i>p</i> -Nitrosophenol).	123.05	-----	713.5	2,985.9	-----	226; cf. 222.
C ₇ H ₇ NO-----	Benzaldoxime (s).	121.07	-----	907.2	3,793.9	-----	93.
C ₉ H ₉ NO-----	Methyl phenyl ketoxime (s).	135.08	-----	1,054.4	4,409.5	-----	93.
C ₁₀ H ₇ NO ₂ -----	α -Naphthoquinone oxime (s) (α -Nitroso- α -naphthol).	173.07	-----	1,163.5	4,868.3	-----	225; cf. 222.
C ₁₀ H ₇ NO ₂ -----	β -Naphthoquinone oxime (s) (β -Nitroso- α -naphthol).	173.07	-----	1,167.4	4,885.6	-----	225; cf. 222.
C ₁₀ H ₇ NO ₂ -----	β -Naphthoquinone oxime (s) (α -Nitroso- β -naphthol).	173.07	-----	1,166.7	4,882.6	-----	225; cf. 222.
C ₁₀ H ₁₃ NO ₂ -----	Oxime of opianic anhydride ⁵⁵ .	-----	-----	1,152.3	4,822.4	-----	108.
C ₁₀ H ₁₃ NO ₂ -----	Thymoquinone oxime (s).	179.11	-----	1,331.8	5,573.6	-----	225; cf. 222.
C ₁₃ H ₁₁ NO-----	Diphenyl ketoxime (s).	197.10	-----	1,626.8	6,803.3	-----	225; cf. 93.

⁵⁵ Stohmann, communicated by Liebermann (Ber., 25, p. 89; 1892.) Formula and molecular weight not indicated. He does not specify whether the above value refers to constant volume or constant pressure.

86. NITROSAMINES⁵⁶

C ₂ H ₆ N ₂ O-----	Dimethylnitrosamine.	74.07	-----	394.5	1,650.9	-----	212.
C ₈ H ₁₀ N ₂ O-----	Ethylphenylnitrosamine (s).	150.10	-----	1,118.4	4,680.5	-----	212.
C ₁₂ H ₁₆ N ₂ O-----	Diphenylnitrosamine (s).	198.10	-----	1,532.6	6,413.9	-----	132.

⁵⁶ See also article by Delépine (C. R., 123, p. 650; 1896) for nitroso and nitro compounds of hexamethylene tetramine.

87. NITRAMINES

C ₂ H ₆ N ₂ O ₂ -----	Ethylnitramine ⁵⁷ .	90.06	-----	372.5	1,557.8	-----	211.
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⁵⁷ CH₃.CH₂.NH.NO₂.

88. NITROSO COMPOUNDS

C ₆ H ₄ N ₂ O ₄ -----	Dinitrosoresorcinol (s).	168.05	-----	⁵⁸ 582.5	2,437.8	-----	212.
C ₉ H ₁₀ N ₂ O-----	<i>p</i> -Nitrosodimethylaniline (s).	150.10	-----	⁵⁹ 1,124.7	4,706.9	-----	212; cf. 132.
C ₁₂ H ₁₆ N ₂ O-----	<i>p</i> -Nitrosodiphenylamine (s).	198.10	-----	1,526.9	6,335.5	-----	132.

⁵⁸ The author (212) gives as the mean value 3,473 cal/g. In his calculation of the molecular heat of combustion he employs 186 as the molecular weight instead of 168.05. The article contains, also, the heats of reaction of a large number of compounds with nitrous acid. For a detailed treatment of this subject consult Ber., 43, p. 1470; 1910; 44, p. 2429; 1911.

⁵⁹ The author (212) gives also the heat of combustion of nitrosodimethylaniline hydrochloride as 4,687.2 kilo-joules.

89. AZO COMPOUNDS

C ₁₂ H ₁₀ N ₂ -----	Azobenzene (s).	182.10	-----	$\left\{ \begin{array}{l} 1,555.2 \\ 1,552.6 \\ 1,545.9 \\ 1,502.0 \end{array} \right.$	6,508.5	-----	147.
C ₁₂ H ₁₀ N ₂ O-----	<i>p</i> -Hydroxyazobenzene (s).	198.10	-----		6,497.6	-----	100.
C ₁₂ H ₁₁ N ₃ -----	<i>p</i> -Aminoazobenzene (s).	197.12	-----		6,469.6	-----	217. ⁶⁰
C ₁₂ H ₁₂ N ₄ -----	2,4-Diaminoazobenzene (s) (Chrysoidine).	212.14	-----		6,285.9	-----	101.
C ₁₄ H ₁₄ N ₂ O ₂ -----	<i>p</i> -Azoanisole.	242.13	-----	1,796.4	7,517.9	-----	101.
C ₁₀ H ₁₈ N ₂ O-----	<i>p</i> -Azophenetole (s).	270.16	-----	2,100.0	8,788.5	-----	101.

⁶⁰ Undoubtedly the best value is that of (217).

VIII. TABLES OF DATA—Continued

3. N COMPOUNDS—Continued

90. SUBSTITUTED HYDRAZINES

Formula	Name	Molecular weight	Number of electrons	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₆ H ₅ N ₂ -----	Phenylhydrazine (s)-----	108.08	-----	{ 875.4 805.4	{ 3,663.6 3,370.6	-----	100. 147.
C ₇ H ₁₀ N ₂ -----	Methylphenylhydrazine (s) (<i>asym.</i>).-----	122.10	-----	1,038.1	4,344.5	-----	100.
C ₁₂ H ₁₂ N ₂ -----	Hydrazobenzene (s)-----	184.12	-----	{ 1,597.3 1,598.8	{ 6,684.7 6,690.9	-----	100. 147.

91. DIAZONIUM COMPOUNDS

C ₆ H ₅ N ₃ O ₃ -----	Benzenediazonium nitrate (s).-----	167.07	-----	782.6	3,275.2	-----	45.
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92. AZOXY COMPOUNDS

C ₁₂ H ₁₀ N ₂ O-----	Azoxybenzene (s)-----	198.10	-----	{ 1,534.5 1,530.1	{ 6,421.9 6,403.5	-----	101. 147.
C ₁₄ H ₁₆ N ₄ O-----	<i>m</i> -Azoxytoluidine (s)-----	256.17	-----	1,903.4	7,965.7	-----	101.
C ₁₆ H ₁₈ N ₂ O ₃ -----	<i>p</i> -Azoxyphenetole (s)-----	286.13	-----	2,098.4	8,781.8	-----	101.
C ₁₆ H ₁₈ N ₂ O ₃ -----	<i>o</i> -Azoxyphenetole (s)-----	286.13	-----	2,068.0	8,730.3	-----	101.

93. ESTERS OF NITRIC AND NITROUS ACID

C ₂ H ₅ NO ₂ -----	Ethyl nitrite (v)-----	75.0	-----	332.6	1,390.9	-----	223.
C ₂ H ₅ NO ₃ -----	Ethyl nitrate (v)-----	91.0	-----	322.4	1,343.3	-----	223.
C ₃ H ₅ N ₃ O ₉ -----	Trinitroglycerol-----	227.06	-----	432.4	1,809.6	-----	81.
C ₄ H ₉ NO ₂ -----	Isobutyl nitrite (v)-----	103.0	-----	644.6	2,695.7	-----	223.

4. HALOGEN AND SULPHUR COMPOUNDS

94. FLUORINE COMPOUNDS

(a) FLUORO-HYDROCARBONS (ALIPHATIC)

C ₇ H ₁₅ F-----	<i>n</i> -Heptyl fluoride-----	118.12	-----	1,121.5	4,690.1	-----	211.
C ₈ H ₁₇ F-----	<i>n</i> -Octyl fluoride (from bromide).-----	132.13	-----	1,271.0	5,315.3	-----	211.
C ₈ H ₁₇ F-----	<i>n</i> -Octyl fluoride (from iodide).-----	132.13	-----	⁶¹ 1,266.4	5,296.1	-----	211.

⁶¹ The B. P. of the product prepared from the iodide is 0.6° higher than the one prepared from the bromide. See also Ber., 55, p. 3378; 1922.

(B) FLUORO-HYDROCARBONS (AROMATIC)

C ₆ H ₅ F-----	Fluorobenzene-----	96.05	-----	747.2	3,124.8	-----	211.
C ₆ H ₄ F ₂ -----	<i>p</i> -Difluorobenzene-----	114.05	-----	706.1	2,952.9	-----	211.
C ₇ H ₇ F-----	<i>o</i> -Fluorotoluene-----	110.05	-----	903.2	3,777.2	-----	211.
C ₇ H ₇ F-----	<i>p</i> -Fluorotoluene-----	110.05	-----	903.0	3,776.3	-----	211.
C ₇ H ₅ F ₂ -----	<i>o</i> -Difluorotoluene (s)-----	128.05	-----	856.9	3,583.6	-----	211.
C ₇ H ₅ F ₃ -----	<i>ω</i> -Trifluorotoluene (s)-----	146.05	-----	810.3	3,388.7	-----	211.
C ₉ H ₁₁ F-----	Fluoropseudocumene (s)-----	138.1	-----	1,208.5	5,053.9	-----	211.

(C) FLUORO-ALCOHOLS (ALIPHATIC)

C ₂ H ₅ OF-----	Fluoroethanol-----	64.05	-----	290.4	1,214.5	-----	211.
C ₂ H ₄ OF ₂ -----	Difluoroethanol-----	82.02	-----	245.8	1,027.9	-----	211.

VIII. TABLES OF DATA—Continued

4. HALOGEN AND SULPHUR COMPOUNDS—Continued

94. FLUORINE COMPOUNDS—Continued

(D) FLUORO-PHENOLS

Formula	Name	Molecular weight	Number of electrons	Kg-cal/s (experimental)	Kilo-joules (K. J.)	Kg-cal/s (calculated to the liquid state)	Literature
C ₆ H ₅ OF-----	<i>o</i> -Fluorophenol-----	112.05	-----	705.8	2,951.7	-----	211.
C ₆ H ₅ OF-----	<i>m</i> -Fluorophenol-----	112.05	-----	696.6	2,913.2	-----	211.
C ₆ H ₅ OF-----	<i>p</i> -Fluorophenol (s) (Stable modif., M. P. 48.2°).	112.05	-----	696.6	2,913.2	-----	211.
C ₇ H ₅ OF ₃ -----	Trifluoro- <i>m</i> -cresol-----	162.05	-----	763.4	3,192.5	-----	211.

(E) ESTERS OF FLUORO-ALCOHOLS

C ₄ H ₇ O ₂ F-----	Fluoroethyl acetate-----	106.05	-----	499.9	2,090.6	-----	211.
C ₄ H ₆ O ₂ F ₂ -----	Difluoroethyl acetate-----	124.05	-----	455.5	1,904.9	-----	211.

(F) ETHERS OF FLUORO-ALCOHOLS

C ₃ H ₅ OF-----	Ethyl fluoroallyl ether-----	104.07	-----	731.0	3,057.0	-----	211.
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(G) ETHERS OF FLUORO-PHENOLS

C ₈ H ₉ OF-----	<i>m</i> -Fluorophenetol-----	140.05	-----	1,023.1	4,278.6	-----	211.
C ₈ H ₉ OF-----	<i>p</i> -Fluorophenetol-----	140.05	-----	1,019.9	4,265.2	-----	211.

(H) FLUORO-ACIDS ALIPHATIC

C ₂ H ₃ O ₂ F-----	Fluoroacetic acid (s)-----	78.02	-----	170.8	714.3	-----	211.
C ₂ H ₂ O ₂ F ₂ -----	Difluoroacetic acid-----	96.02	-----	134.6	562.9	-----	211.

(I) FLUORO-ACIDS (AROMATIC)

C ₇ H ₅ O ₂ F-----	<i>o</i> -Fluorobenzoic acid (s)-----	140.05	-----	740.2	3,095.5	-----	211.
C ₇ H ₅ O ₂ F-----	<i>m</i> -Fluorobenzoic acid (s)-----	140.05	-----	737.6	3,084.6	-----	211.
C ₇ H ₅ O ₂ F-----	<i>p</i> -Fluorobenzoic acid (s)-----	140.05	-----	739.7	3,093.4	-----	211.
C ₈ H ₅ O ₂ F ₃ -----	<i>m</i> - ω -Trifluorotoluic acid ^{61a} -----	190.05	-----	807.1	3,375.4	-----	211.
C ₈ H ₇ O ₂ F-----	(s). α -Fluorocinnamic acid (s)-----	166.06	-----	1,013.6	4,238.9	-----	211.

^{61a} *m*-F₃C-C₆H₄.COOH.

(J) ESTERS OF FLUORO-ACIDS (ALIPHATIC)

C ₄ H ₇ O ₂ F-----	Ethyl fluoroacetate-----	106.05	-----	503.1	2,103.9	-----	211.
C ₄ H ₆ O ₂ F ₂ -----	Ethyl difluoroacetate-----	124.05	-----	436.5	1,825.4	-----	211.

(K) ESTERS OF FLUORO-ACIDS (AROMATIC)

C ₉ H ₉ O ₂ F-----	Ethyl <i>p</i> -fluorobenzoate (s)-----	168.05	-----	1,060.1	4,433.3	-----	211.
C ₁₀ H ₉ O ₂ F-----	Methyl α -fluorocinnamate (s).-----	180.05	-----	1,187.5	4,966.1	-----	211.

(L) FLUORO-AMIDES (ALIPHATIC)

C ₂ H ₄ ONF-----	Fluoroacetamide (s)-----	77.05	-----	250.0	1,045.5	-----	211.
C ₂ H ₃ ONF ₂ -----	Difluoroacetamide (s)-----	95.05	-----	208.3	871.1	-----	211.

VIII. TABLES OF DATA—Continued

4. HALOGEN AND SULPHUR COMPOUNDS—Continued

94. FLUORINE COMPOUNDS—Continued

(M) FLUORO-AMIDES (AROMATIC)

Formula	Name	Molecular weight	Number of electrons	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₈ H ₇ ONF ₂ -----	Difluoroacetanilide (s)-----	171.06	-----	944.8	3,951.2	-----	211.
C ₈ H ₅ ONF ₃ -----	<i>m</i> -Trifluoroacetotoluide (s)-----	203.75	-----	1,043.2	4,362.7	-----	211.

(N) FLUORO-AMINES (ALIPHATIC)

C ₂ H ₅ NF ₂ -----	Difluoroethylamine-----	81.05	-----	326.1	1,363.8	-----	211.
C ₄ H ₇ NF ₄ -----	Tetrafluorodiethylamine-----	145.06	-----	566.1	2,367.4	-----	211.

(O) FLUORO-NITRAMINES (ALIPHATIC)

C ₂ H ₄ O ₂ N ₂ F ₂ ---	Difluoroethylnitramine (s) (M. P. 22.4°).	126.06	-----	290.6	1,215.3	-----	211.
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(P) FLUORO-NITROBENZENES

C ₆ H ₄ O ₂ NF-----	<i>o</i> -Fluoronitrobenzene-----	141.05	-----	707.5	2,958.8	-----	211.
C ₆ H ₄ O ₂ NF-----	<i>m</i> -Fluoronitrobenzene-----	141.05	-----	706.4	2,954.2	-----	211.
C ₆ H ₄ O ₂ NF-----	<i>p</i> -Fluoronitrobenzene (s)-----	141.05	-----	703.0	2,939.9	-----	211.
C ₆ H ₃ O ₂ NF ₂ -----	1,4-Difluoro-2-nitrobenzene-----	159.04	-----	673.1	2,814.9	-----	211.
C ₆ H ₃ O ₄ N ₂ F-----	2,4-Dinitro-1-fluorobenzene (s).	186.05	-----	669.3	2,799.0	-----	211.

(Q) FLUORO-NITROTOLUENES

C ₇ H ₄ O ₂ NF ₃ ----	<i>m</i> -Nitrobenzotrifluoride-----	191.05	-----	771.5	3,226.4	-----	211.
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(R) FLUORO-ANILINES

C ₆ H ₅ NF-----	<i>o</i> -Fluoroaniline-----	111.05	-----	778.2	3,254.4	-----	211.
C ₆ H ₅ NF-----	<i>m</i> -Fluoroaniline-----	111.05	-----	771.1	3,249.8	-----	211.
C ₆ H ₅ NF-----	<i>p</i> -Fluoroaniline-----	111.05	-----	782.2	3,271.2	-----	211.

(S) FLUORO-ANILIDES

C ₈ H ₅ ONF-----	<i>m</i> -Fluoroacetanilide (s)-----	153.07	-----	978.1	4,090.4	-----	211.
C ₈ H ₅ ONF-----	<i>p</i> -Fluoroacetanilide (s)-----	153.07	-----	978.9	4,093.8	-----	211.

(T) FLUORO-NITROPHENOLS AND NITROPHENETOLS

C ₆ H ₄ O ₃ NF-----	3-Nitro-4-fluorophenol (s)---	157.04	-----	652.8	2,730.0	-----	211.
C ₆ H ₅ O ₃ NF-----	3-Nitro-4-fluorophenetol (s)---	185.07	-----	981.4	4,104.21	-----	211.

(U) FLUORO-NITRANILINES AND NITRACETANILIDES

C ₆ H ₅ O ₂ N ₂ F----	3-Nitro-4-fluoroaniline (s)---	156.04	-----	736.9	3,081.7	-----	211.
C ₆ H ₇ O ₃ N ₂ F----	3-Nitro-4-fluoroacetanilide---	198.06	-----	936.2	3,915.2	-----	211.

VIII. TABLES OF DATA—Continued

4. HALOGEN AND SULPHUR COMPOUNDS—Continued

95. CHLORINE COMPOUNDS

(A) CHLORINATED HYDROCARBONS ⁶²

Formula	Name	Molecular weight	Number of electrons	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
CH ₃ Cl-----	Methyl chloride (g)-----	50.5	-----	{ 164.2 173.2	686.7 724.8	-----	223. 14.
CH ₂ Cl ₂ -----	Methylene chloride (v)-----	85.0	-----	⁶³ 106.8	446.9	-----	40.
CHCl ₃ -----	{ Chloroform (v)----- Chloroform (liq.)-----	119.5	-----	{ 70.3 89.2	293.9 373.3	-----	223. 17.
CCl ₄ -----	{ Carbon tetrachloride (v)----- Carbon tetrachloride (liq.)-----	154.0	-----	{ 44.5 37.3	186.2 156.1	-----	17. 17.
C ₂ H ₅ Cl-----	Ethyl chloride (v)-----	64.5	-----	{ 316.7 326.9	1,324.4 1,368.1	-----	223. 14.
C ₂ H ₄ Cl ₂ -----	Ethylene chloride (v)-----	99.0	-----	271.0	1,133.3	-----	223.
C ₂ H ₄ Cl ₂ -----	{ Ethylidene chloride (v)----- Ethylidene chloride (liq.)-----	99.0	-----	{ 271.1 ⁶⁴ 267.1	1,133.7 1,117.8	-----	223. 40.
C ₂ Cl ₆ -----	Hexachloroethane (s)-----	237.0	-----	110.0	460.4	-----	17.
C ₂ H ₃ Cl-----	Chloroethylene (v)-----	62.5	-----	281.5	1,177.2	-----	223.
C ₂ Cl ₄ -----	Tetrachloroethylene-----	166.0	-----	162.5	680.1	-----	17.
C ₃ H ₇ Cl-----	Propyl chloride (v)-----	78.5	-----	478.3	2,000.3	-----	223.
C ₃ H ₈ Cl ₂ -----	Dimethyldichloromethane (Acetone chloride) (v)-----	112.9	-----	427.8	1,789.1	-----	223.
C ₃ H ₅ Cl-----	Chloropropylene (v)-----	76.5	-----	439.5	1,838.0	-----	223.
C ₃ H ₃ Cl-----	Allyl chloride (v)-----	76.5	-----	440.8	1,843.4	-----	223.
C ₃ H ₄ Cl ₂ -----	Dichlorotrimethylene-----	111.0	-----	426.0	1,782.8	-----	36.
C ₄ H ₉ Cl-----	Isobutyl chloride-----	92.5	-----	635.5	2,657.7	-----	223.
C ₆ H ₄ Cl ₂ -----	<i>o</i> -Dichlorobenzene (s)-----	147.0	-----	671.8	2,811.5	-----	17.
C ₆ Cl ₆ -----	Hexachlorobenzene (s)-----	285.0	-----	509.0	2,130.2	-----	17.
C ₇ H ₇ Cl-----	Benzyl chloride-----	126.5	-----	886.4	3,706.9	-----	179.
C ₁₀ H ₁₆ HCl-----	Camphene hydrochloride-----	172.5	-----	1,469.8	6,146.7	-----	32.
C ₁₀ H ₁₆ .2HCl-----	Terpene dihydrochloride-----	209.0	-----	1,467.7	6,137.9	-----	32.
C ₁₀ H ₁₆ HCl-----	Terebenthene hydrochloride (cryst.)-----	172.5	-----	1,469.2	6,144.2	-----	32.
C ₁₃ H ₁₁ Cl-----	Diphenylchloromethane (s)-----	202.5	-----	1,617.3	6,763.6	-----	179.
C ₁₉ H ₁₅ Cl-----	Triphenylchloromethane (s)-----	278.0	-----	2,348.5	9,821.4	-----	179.

⁶² These compounds are not arranged in classes, but are given according to the number of carbon atoms they contain. In view of the relatively large error in the determinations, the molecular weights are all rounded off. All the data except Thomsen's determinations, or unless otherwise indicated, refer to the formation of a dilute solution of hydrochloric acid. Thomsen's determinations are calculated to the production of gaseous hydrogen chloride. No vacuum correction was applied to any of the values. It is impossible to calculate the heats of combustion of these compounds with any degree of precision, for the amounts of water used in the respective combustions are not specified by any of the writers (except Thomsen) and, hence, it is impossible to correct the values for the heat of dilution of the hydrogen chloride formed.

⁶³ HCl-gas.

⁶⁴ HCl-gas.

(B) COMPOUNDS OF C, H, O AND CL (ALIPHATIC)

C ₂ H ₅ OCl-----	Monochloroacetaldehyde-----	73.5	-----	234.4	980.3	-----	157.
C ₂ H ₃ O ₂ Cl-----	Monochloroacetic acid (s)-----	94.5	-----	171.0	715.6	-----	36.
C ₂ H ₃ O ₂ Cl ₃ -----	Trichloroacetic acid (s)-----	163.5	-----	92.8	388.4	-----	36.
C ₄ H ₇ O ₂ Cl-----	Ethyl monochloroacetate-----	122.5	-----	493.9	2,065.5	-----	157.
C ₄ H ₅ O ₂ Cl ₂ -----	Ethyl dichloroacetate-----	157.0	-----	493.4	1,937.9	-----	157.

(C) COMPOUNDS OF C, H, O AND CL (AROMATIC)

C ₇ H ₅ OCl-----	Benzoyl chloride-----	140.5	-----	782.8	3,273.7	-----	157.
C ₇ H ₅ O ₂ Cl-----	<i>o</i> -Chlorobenzoic acid (s)-----	156.5	-----	734.5	3,071.7	-----	157.
C ₇ H ₅ O ₂ Cl-----	<i>p</i> -Chlorobenzoic acid (s)-----	156.5	-----	726.6	3,038.6	-----	157.
C ₇ H ₄ OCl ₂ -----	<i>o</i> -Chlorobenzoyl chloride (s)-----	175.0	-----	741.5	3,100.9	-----	157.
C ₇ H ₅ O ₂ Cl-----	Chlorosalicylaldehyde ⁶⁵ -----	156.5	-----	746.3	3,121.0	-----	157.
C ₈ H ₇ OCl-----	<i>o</i> -Toluyyl chloride (s)-----	154.5	-----	944.0	3,947.8	-----	157.
C ₈ H ₄ O ₂ Cl ₂ -----	Phthalyl chloride (s)-----	203.0	-----	801.8	3,353.1	-----	157.
C ₈ H ₅ O ₂ Cl-----	Ethyl <i>o</i> -chlorobenzoate-----	184.5	-----	1,065.8	4,467.2	-----	157.

⁶⁵ The position of the chlorine atom in the molecule is not given.

VIII. TABLES OF DATA—Continued

4. HALOGEN AND SULPHUR COMPOUNDS—Continued

95. CHLORINE COMPOUNDS—Continued

(D) CHLOROHYDROQUINOLS

Formula	Name	Molecular weight	Number of electrons	Kg-cal ₁₅ (experimental)	Kilo-joules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₆ H ₃ O ₂ Cl-----	Chlorohydroquinol (s)-----	144.5	-----	645.9	2,703.1	-----	225; cf. 222.
C ₆ H ₄ O ₂ Cl ₂ -----	2,6-Dichlorohydroquinol (s)....	179.0	-----	616.6	2,568.2	-----	225; cf. 222.
C ₆ H ₃ O ₂ Cl ₃ -----	Trichlorohydroquinol (s)-----	213.5	-----	593.0	2,481.7	-----	225; cf. 222.
C ₆ H ₂ O ₂ Cl ₄ -----	Tetrachlorohydroquinol (s)-----	248.0	-----	562.8	2,355.3	-----	225; cf. 223.

(E) CHLOROQUINONES

C ₆ H ₂ O ₄ Cl ₂ -----	Chloranilic acid (s)-----	209.0	-----	484.9	-----	2,029.3	225; cf. 222.
C ₆ H ₃ O ₂ Cl-----	Chloroquinone (s)-----	142.5	-----	616.6	-----	2,580.5	225; cf. 222.
C ₆ H ₂ O ₂ Cl ₂ -----	2,6-Dichloroquinone (s)-----	177.0	-----	578.9	-----	2,422.7	225; cf. 222.
C ₆ H ₃ O ₂ Cl ₃ -----	Trichloroquinone (s)-----	211.5	-----	546.4	-----	2,286.7	225; cf. 222.
C ₆ O ₂ Cl ₄ -----	Tetrachloroquinone (s) (Chloranil).	246.0	-----	517.7	-----	2,166.6	225; cf. 222.

(F) CHLORINE COMPOUNDS OF C, H, O, N

C ₂ H ₄ ONCl-----	Chloroacetamide (s)-----	93.5	-----	242.5	1,014.1	-----	157.
C ₂ H ₂ ONCl ₃ -----	Trichloroacetamide (s)-----	162.5	-----	165.2	690.9	-----	157.

96. ALKYL BROMIDES ⁶⁵

CH ₃ Br-----	Methyl bromide (v)-----	95	-----	{ 184.0 180.4	{ 769.5 754.9	-----	223. 14.
C ₂ H ₅ Br-----	Ethyl bromide (v)-----	109.0	-----	{ 340.5 329.5	{ 1,423.9 1,378.9	-----	223. 14.
C ₃ H ₇ Br-----	Propyl bromide (v)-----	123.0	-----	497.3	2,079.7	-----	223.

⁶⁶ See footnote 62, p. 418, under chlorinated hydrocarbons. The final product of combustion in the case of the bromine derivatives is bromine vapor.

97. IODINE COMPOUNDS ⁶⁷

CH ₃ I-----	{ Methyl iodide (v)----- Methyl iodide (liq.)-----	142.0	-----	{ 200.5 194.7	{ 838.5 814.8	-----	223. 21.
CH ₂ I ₂ -----	Methylene iodide-----	268.0	-----	178.4	746.6	-----	21.
CHI ₃ -----	Iodoform (s)-----	394.0	-----	161.9	677.6	-----	21.
C ₂ H ₅ I-----	{ Ethyl iodide (v)----- Ethyl iodide (liq.)-----	156.0	-----	{ 357.8 356.0	{ 1,496.3 1,489.9	-----	223. 21.
C ₂ H ₄ I ₂ -----	Ethylene iodide (s)-----	282.0	-----	324.8	1,359.3	-----	21.
C ₂ I ₄ -----	Tetraiodoethylene (s)-----	534.0	-----	261.6	1,094.8	-----	21.
C ₃ H ₇ I-----	n-Propyl iodide-----	170.0	-----	514.3	2,152.3	-----	21.
C ₃ H ₇ I-----	Isopropyl iodide-----	170.0	-----	509.1	2,130.6	-----	21.
C ₃ H ₅ I-----	Allyl iodide-----	168.0	-----	478.3	2,001.7	-----	21.
C ₄ H ₉ NI-----	Tetraiodopyrrol (s) (Iodol)....	571.0	-----	503.1	2,105.5	-----	21.
C ₆ H ₅ I-----	Phenyl iodide-----	264.0	-----	770.7	3,225.4	-----	21.
C ₆ H ₅ NI-----	Iodoaniline-----	225.0	-----	810.7	3,392.8	-----	170.
C ₇ H ₅ O ₂ I-----	o-Iodobenzoic acid (s)-----	248.0	-----	769.6	3,220.8	-----	21.
C ₇ H ₅ O ₃ I-----	Iodosalicylic acid (s)-----	264.0	-----	706.4	2,956.3	-----	21.
C ₇ H ₄ O ₃ I ₂ -----	Diiodosalicylic acid (s)-----	390.0	-----	699.9	2,929.1	-----	21.

⁶⁷ It is claimed that all the iodo compounds give upon combustion iodine and only inappreciable amounts of HI or HIO₃. Under the conditions of the experiments solid iodine is always the end product. Individual determinations do not agree better than 0.5 to 1.0 per cent.

VIII. TABLES OF DATA—Continued

4. HALOGEN AND SULPHUR COMPOUNDS—Continued

98. SULPHUR COMPOUNDS⁶⁸

Formula	Name	Molecular weight	Number of electrons	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
COS	Carbonyl sulphide (g)	60.0		130.5	545.8		223.
	{ Carbon disulphide (v)	76.0		257.7	1,077.7		223.
CS ₂	{ Carbon disulphide (liq.)	76.0		⁶⁹ 246.6	1,032.0		13.
				394.5	1,650.9		17.
CH ₄ S	Methyl mercaptan (v)	48.0		297.6	1,244.6		223.
CH ₄ N ₂ S	Thiourea (s)	76.0		⁷⁰ 342.8	1,434.6		130.
C ₂ H ₆ S	{ Ethyl mercaptan (v)	62.0		452.0	1,890.3		223.
	{ Ethyl mercaptan (liq.)	62.0		517.2	2,164.5		22.
C ₂ H ₆ S	Dimethyl sulphide (v)	62.0		455.6	1,905.3		223.
C ₂ H ₃ NS	{ Methyl thiocyanate (v)	73.0		397.4	1,661.9		223.
	{ Methyl thiocyanate (liq.)			453.1	1,896.2		20.
C ₂ H ₃ NS	{ Methyl isothiocyanate (v)	73.0		390.5	1,633.1		223.
	{ Methyl mustard oil.						
	{ Methyl isothiocyanate (v)			442.9	1,853.5		20.
	{ Methyl isothiocyanate (s).						
C ₂ H ₇ O ₂ NS	Taurine (s)	125.0		382.9	1,602.4		17.
C ₃ H ₅ NS	Ethyl thiocyanate	87.0		613.8	2,568.8		20.
C ₃ H ₅ NS	Ethyl isothiocyanate (ethyl mustard oil).	87.0		604.1	2,528.2		20.
C ₃ H ₅ O ₂ N ₂ S	Thiohydantoic acid (s)	134.0		498.5	2,086.2		130.
C ₃ H ₄ ON ₂ S	Thiohydantoine (s)	116.1		503.0	2,105.1		130.
C ₄ H ₁₀ S	{ Diethyl sulphide (v)	90.0		769.2	3,216.8		223.
	{ Diethyl sulphide (liq.)			829.5	3,471.5		22.
C ₄ H ₉ NS ₂	Dimethyl N-methylcarbimidothiolate ⁷¹	103.0		969.2	4,056.1		61.
C ₄ H ₉ NS ₂	S-Methyl N-dimethyldithiocarbamate (sol.). ⁷²	103.0		953.9	3,992.1		61.
C ₄ N ₆ NS ₂	Methyl formothialdine ⁷³	103.0		964.5	4,036.4		61.
C ₄ H ₈ N ₂ S	Thiosinamine (s)	116.0		791.8	3,313.7		20.
C ₄ H ₈ NS	{ Allyl mustard oil.	99.0		732.5	3,065.5		20.
	{ Allyl mustard oil (v)			672.8	2,813.6		223.
C ₄ H ₄ S	Thiophene	84.0		670.5	2,806.0		37.
	Thiophene (v)			608.2	2,543.5		223.
C ₅ H ₁₁ NS ₂	Dimethyl N-ethylcarbimide-dithiolate. ⁷⁴	117.0		1,130.1	4,729.5		61.
C ₅ H ₁₁ NS ₂	S-Ethyl ester N-dimethyldithiocarbamate. ⁷⁵	117.0		1,122.0	4,695.6		61.
C ₅ H ₁₀ N ₂ S ₂	Dimethyl formocarbithialdine (sol.). ⁷⁶	130		1,098.4	4,596.8		61.
C ₅ H ₁₀ N ₂ S ₂	Carbithialdine (sol.). ⁷⁷	130.0		1,085.8	4,544.1		61.
C ₅ H ₁₀ N ₂ S ₂	Pentamethylenediamine disulfine (sol.). ⁷⁸	130.0		1,112.7	4,656.7		61.

⁶⁸ The data of (223) refer to the formation of gaseous SO₂. All other values, unless otherwise indicated, refer to the production of a dilute solution of sulphuric acid. Cf. the recent paper of A. Mennucci, *Rev. facultad. cienc. quim.*, 2, p. 25; 1924. This author states that complete oxidation of sulphur derivatives to SO₃ does not occur even at 25 atm. with an evolution of 10,000 calories of heat. The results of the different investigators are not comparable and can not be brought to a comparable basis, for the amount of water used in the bombs is not in all cases specified. In view of the relatively large error that may thus be introduced, all molecular weights are given in round numbers, and no vacuum or other corrections have been applied to the values of any investigator except that the usual correction has been applied to work of (223).

⁶⁹ Gaseous SO₂.

⁷⁰ Bomb contained exactly 25 cm³ H₂O. Final state of H₂SO₄ corresponds to H₂SO₄. 200 H₂O.

⁷¹ CH₃.N=C=(SCH₃)₂.

⁷² (CH₃)₂NC=S-SCH₃.

⁷³ H₂C < $\begin{matrix} \text{S}-\text{CH}_2 \\ \text{S}-\text{CH}_2 \end{matrix}$ > NCH₃.

⁷⁴ C₂H₅N=C(SCH₃)₂.

⁷⁵ (CH₃)₂N-C < $\begin{matrix} \text{S} \\ \text{S}-\text{C}_2\text{H}_5 \end{matrix}$ >.

⁷⁶ CS₂ (CH₂=N-CH₃)₂.

⁷⁷ CS₂ (CH₃C=NH)₂.

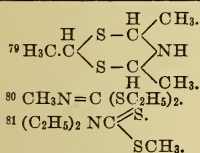
⁷⁸ H₃C < $\begin{matrix} \text{S}-\text{CH}_2 \\ \text{S}-\text{CH}_2 \end{matrix}$ > NCH₂N=CH₂.

VIII. TABLES OF DATA—Continued

4. HALOGEN AND SULPHUR COMPOUNDS—Continued

98. SULPHUR COMPOUNDS—Continued

Formula	Name	Molecular weight	Number of electrons	Kg-cal ₁₅ (experimental)	Kilojoules (K. J.)	Kg-cal ₁₅ (calculated to the liquid state)	Literature
C ₅ H ₈ O ₂ S-----	Tetrahydro- α -thiophenecarboxylic acid (s).	130.2	-----	754.8	3,156.6	-----	185.
C ₅ H ₄ O ₂ S-----	α -Thiophenecarboxylic acid (s).	128.0	-----	646.2	2,702.4	-----	185.
C ₆ H ₁₃ NS ₂ -----	Thialdine (sol). ⁷⁹	131.0	-----	1,263.6	5,288.2	-----	61.
C ₆ H ₁₃ NS ₂ -----	Diethyl N-methylcarbimidedithiolate. ⁸⁰	131.0	-----	1,289.4	5,396.1	-----	61.
C ₆ H ₁₃ NS ₂ -----	S-Methyl N-diethyldithiocarbamate. ⁸¹	131.0	-----	1,271.7	5,322.0	-----	61.
C ₆ H ₁₂ O ₄ N ₂ S ₂ -----	Cystine (s)-----	240.25	-----	⁸² 993.9	4,156.5	-----	19.
C ₇ H ₈ NS ₂ -----	Phenyl mustard oil-----	135.0	-----	1,024.3	4,286.7	-----	22.
C ₉ H ₁₁ NS ₂ -----	Dimethyl N-phenylcarbimidedithiolate (sol.). ⁸³	165.0	-----	1,544.5	6,463.7	-----	61.
C ₁₈ H ₁₄ O ₂ N ₂ S-----	Benzonaphthoquinone thiazine (s).	322.20	-----	2,278.1	9,533.8	-----	178.

⁸² Gaseous SO₂.⁸³ C₆H₅N=C (SCH₃)₂

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3. N COMPOUNDS

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$\text{C}_4\text{H}_9\text{N}_3\text{O}_2$ -----	407	$\text{C}_7\text{H}_8\text{NO}$ -----	405		
		$\text{C}_7\text{H}_8\text{NO}_3$ -----	410		
$\text{C}_4\text{H}_9\text{N}_2\text{O}_2$ -----		$\text{C}_7\text{H}_{10}\text{N}_2$ -----	415		
H_2O -----	407	$\text{C}_{12}\text{H}_{11}\text{N}_2\text{Ag}$ -----	410		
$\text{C}_4\text{H}_9\text{N}$ -----	404	$\text{C}_7\text{H}_{13}\text{NO}_3$ -----	406		
$\text{C}_4\text{H}_9\text{N}_4\text{O}$ -----	408	$\text{C}_7\text{H}_{13}\text{N}_2\text{O}_2$ -----	407		
C_5 $\text{C}_5\text{H}_4\text{N}_4\text{O}$ -----	408	$\text{C}_7\text{H}_{14}\text{N}_2\text{O}_2$ -----	407		
$\text{C}_5\text{H}_4\text{N}_4\text{O}_3$ -----	408				
$\text{C}_5\text{H}_4\text{N}_4\text{O}_3$ -----	403				

X. INDEX OF COMPOUNDS, BY FORMULA—Continued

3. N COMPOUNDS—Continued

Formula	Page	Formula	Page	Formula	Page
C₁₂ C ₁₂ H ₁₃ N ₄	414	C₁₆ C ₁₆ H ₁₃ N ₃ O ₄	408	C₂₀ C ₂₀ H ₂₁ NO ₄	409
C ₁₂ H ₁₄ N ₄ O ₈	408	C ₁₆ H ₁₃ N.....	405	C ₂₀ H ₂₇ NO ₁₁	409
C ₁₂ H ₁₄ N ₄ O ₈	408	C ₁₆ H ₁₃ N ₃ O ₃	407	C ₂₁ H ₁₃ N ₃ O ₅	412
C ₁₂ H ₂₂ N ₂ O ₃	406	C ₁₆ H ₁₅ N ₃ O ₃	407	C ₂₁ H ₂₁ N.....	404
C ₁₂ H ₂₇ N.....	404	C ₁₆ H ₁₅ N ₂ O ₂	407		
C₁₃ C ₁₃ H ₁₁ NO.....	467, 414	C ₁₆ H ₁₅ N ₂ O ₂	414	C ₂₁ H ₂₂ N ₂ O ₂	409
C ₁₃ H ₁₂ N ₂ O.....	407	C ₁₆ H ₁₅ N ₂ O ₃	415	C ₂₂ H ₂₃ NO ₇	409
C₁₄ C ₁₄ H ₉ NO ₄	412	C ₁₇ H ₁₆ NO ₃ H ₂ O.....	409	C ₂₂ H ₂₃ N ₂ O ₄	409
C ₁₄ H ₁₁ N ₂ O ₃	414	C₁₈ C ₁₈ H ₁₅ N.....	405	C ₂₃ H ₂₇ NO ₈	
C ₁₄ H ₁₃ N.....	404	C ₁₈ H ₂₁ NO ₃ H ₂ O.....	409	2H ₂ O.....	409
C ₁₄ H ₁₆ N ₄ O.....	415	C ₁₉ H ₁₃ N ₃ O ₃	411		
C ₁₅ H ₁₃ N.....	404	C ₁₉ H ₁₃ N ₃ O ₇	411		
C₁₆ C ₁₆ H ₁₆ N ₂ O ₂	409	C ₁₉ H ₁₆ N ₃ O.....	405		
C ₁₆ H ₁₁ NO ₂	407	C ₁₉ H ₂₁ NO ₃	409		
C ₁₆ H ₁₁ NO ₅	412				

4. HALOGEN COMPOUNDS

Br		C₃ C ₃ H ₅ ClO ₂	419	C₆ C ₆ H ₅ FO.....	416
CH ₃ Br.....	419	C ₃ H ₅ Cl ₂ O ₂	419	C ₆ H ₅ FN.....	417
C ₂ H ₅ Br.....	419	C ₃ H ₅ Cl ₂	418	C ₇ H ₄ F ₂ NO ₂	417
C ₃ H ₇ Br.....	419	C ₃ H ₅ Cl ₂ O ₂	419	C ₇ H ₅ F ₃	415
		C ₃ H ₅ ClO ₂	419	C ₇ H ₅ FO ₂	416
Cl		C ₃ H ₄ Cl ₂ O.....	418	C ₇ H ₅ F ₃ O.....	416
C₁ CCl ₂	418	C ₃ H ₅ ClO.....	418	C ₇ H ₆ F ₂	415
CHCl ₃	418	C ₇ H ₅ ClO ₂	418	C ₇ H ₇ F.....	415
		C ₇ H ₇ Cl.....	418	C ₇ H ₁₆ F.....	415
CH ₂ Cl ₂	418	C ₈ H ₄ Cl ₂ O ₂	418		
CH ₃ Cl.....	418	C₈ C ₈ H ₇ ClO.....	418	C₈ C ₈ H ₅ F ₃ O ₂	416
C₂ C ₂ Cl ₂	418	C ₈ H ₉ ClO ₂	418	C ₈ H ₇ FN ₂ O ₃	417
C ₂ Cl ₃	418	C₁₀ C ₁₀ H ₇ Cl.....	418	C ₈ H ₇ F ₂ NO.....	417
C ₂ HCl ₃ O ₂	418	C ₁₀ H ₉ Cl.....	418	C ₈ H ₅ FNO.....	417
		C ₁₀ H ₁₁ Cl.....	418	C ₈ H ₅ FNO ₃	417
C ₂ H ₂ Cl ₂ NO.....	419	C ₁₀ H ₁₃ Cl.....	418		
C ₂ H ₃ Cl.....	418			C ₈ H ₅ FO.....	416
C ₂ H ₃ ClO.....	418	F		C ₈ H ₁₇ F.....	415
C ₂ H ₃ ClO ₂	418	C₂ C ₂ H ₂ F ₂ O ₂	416	C ₈ H ₇ FO ₂	416
C ₂ H ₃ ClNO.....	419	C ₂ H ₃ F ₂ NO.....	416	C ₈ H ₅ F ₃ NO.....	417
		C ₂ H ₃ FO ₂	416	C ₈ H ₉ FO ₂	416
C ₂ H ₄ Cl ₂	418	C ₂ H ₄ FNO.....	416	C ₈ H ₁₁ F.....	415
C ₂ H ₅ Cl.....	418	C ₂ H ₄ F ₂ N ₂ O ₂	417	C ₁₀ H ₉ FO ₂	416
C₃ C ₃ H ₄ Cl ₂	418	C ₂ H ₄ F ₂ O.....	415	I	
C ₃ H ₅ Cl.....	418	C ₂ H ₅ F ₂ N.....	417	CHI ₃	419
C ₃ H ₅ Cl ₂	418	C ₂ H ₅ F ₂ O.....	415	CH ₂ I ₂	419
		C ₂ H ₅ FO.....	416	CHI ₄	419
C ₃ H ₇ Cl.....	418	C₄ C ₄ H ₆ F ₂ O ₂	416	C ₂ I ₄	419
C₄ C ₄ H ₆ Cl ₂ O ₂	418	C ₄ H ₇ F ₄ N.....	417	C ₂ H ₄ I ₂	419
C ₄ H ₇ ClO ₂	418	C ₄ H ₇ FO ₂	416	C ₂ H ₅ I.....	419
C ₄ H ₉ Cl.....	418	C ₄ H ₉ FO.....	416	C ₃ H ₅ I.....	419
C₆ C ₆ Cl ₄ O ₂	419	C₆ C ₆ H ₃ FN ₂ O ₄	417	C ₃ H ₇ I.....	419
		C ₆ H ₃ F ₂ NO ₂	417	C ₃ HLN.....	419
C ₆ Cl ₆	418	C ₆ H ₅ I.....	415	C ₃ H ₅ I.....	419
C ₆ HCl ₅ O ₂	419	C ₆ H ₅ FO ₂	417	C ₃ H ₅ LN.....	419
C ₆ H ₂ Cl ₂ O ₂	419	C ₆ H ₅ IO ₂	417	C ₃ H ₅ IO ₂	419
C ₆ H ₂ Cl ₂ O ₄	419	C ₆ H ₅ F.....	415	C ₇ H ₅ IO ₃	419
C ₆ H ₂ Cl ₇ O ₂	419	C ₆ H ₅ FN ₂ O ₂	417	C ₇ H ₄ IO ₃	419

5. S COMPOUNDS

C₁ COS.....	420	C ₄ C ₄ H ₅ NS.....	420	C ₆ C ₆ H ₉ O ₂ S.....	421
CS ₂	420	C ₄ C ₄ H ₅ N ₂ O ₂ S.....	420	C ₆ C ₆ H ₁₀ N ₂ S ₂	420
CH ₃ N ₂ S.....	420	C ₄ C ₄ H ₅ S.....	420	C ₆ C ₆ H ₁₁ NS ₂	420
CH ₃ S.....	420	C ₄ C ₄ H ₅ NS.....	420	C ₆ C ₆ H ₁₂ N ₂ O ₄ S ₂	421
C₂ C ₂ H ₃ NS.....	420	C ₄ C ₄ H ₅ N ₂ S.....	420	C ₆ C ₆ H ₁₃ NS ₂	421
C ₂ H ₆ S.....	420	C ₄ C ₄ H ₅ NS ₂	420	C ₇ H ₅ NS.....	421
C ₂ H ₇ N ₂ OS.....	420	C ₄ C ₄ H ₁₀ S.....	420	C ₇ H ₁₁ NS ₂	421
C ₂ H ₄ N ₂ OS.....	420	C ₄ C ₄ H ₄ O ₂ S.....	421	C ₁₈ H ₁₄ N ₂ O ₂ S.....	421

